RAPID ASSESSMENT OF HABITAT AND WILDLIFE LOSSES FROM HURRICANE SANDY IN THE HUDSON RARITAN ESTUARY

Hudson River Foundation
New York, NY 10004

Submitted to the National Fish and Wildlife Foundation

December 12, 2012

Prepared By:
Colin Grubel and John Waldman, Queens College, City University of New York
Jim Lodge and Dennis Suszkowski, Hudson River Foundation

Introduction

Hurricane Sandy was a Category 1 hurricane that was downgraded to a post-tropical cyclone when it moved ashore near Atlantic City, NJ, on October 29, 2012. Despite being downgraded, the intensity of the storm in the New York City area was amplified when Sandy merged with another winter storm system. Wind speeds up to 110 mph were recorded. Hurricane Sandy did not bring a large amount of rain compared to other hurricanes, and the harbor area saw only about one inch of precipitation (Friedman). In addition to increased winds and rain, the storm caused a large tidal surge, made even stronger by the concurrence of a spring tide. For example at Battery Park, on the southern tip of Manhattan, the surge (astronomical tide plus storm effect) reached 13.88 feet (NOAA website). Storm-related water level increases were seen as far north along the Hudson River as Troy, NY and surges between 10 and 11 feet were recorded on the Hudson as far as 150 miles from the Battery (USGS Website).

Methods

A survey of eight questions (Appendix I) was conducted with individuals from a variety of organizations in the Hudson-Raritan region. Respondents included resource managers, academics, representatives from NGOs, and knowledgeable private citizens (Appendix II). Fifty interviews were conducted by phone and e-mail between November 15 and November 21, 2012. The survey was designed to assess impacts of Hurricane Sandy on fish and other species within and around the Hudson-Raritan Estuary, including tributaries and watersheds of the Hudson and Raritan Rivers. The survey questions focused on known effects to species or habitats, any effects suspected but not observed, and plans for remediation as well as the comparative effects of Hurricane Irene, a storm in which the primary effects were from heavy precipitation instead of coastal flooding.

Areas Affected

New York Harbor/Raritan Bay

Marine species and habitats are difficult to observe directly, and few of those interviewed had seen any definite effects of the storm on sea life. Most of the statements made about marine species were educated guesses. For example, researchers conducting a study in Gowanus Bay had recently planted eelgrass, *Zostera marina*, marking the beds with tall, wooden stakes. After the storm, Bart Chezar, a researcher, checked the site, and while he could not see the grass itself, he could see that the wooden stakes had survived, strongly indicating that the plants had as well. A formal check of the eelgrass will be made in the spring (Chezar).

In addition, the U.S. Army Corps of Engineers had been conducting a survey of migratory finfish in the harbor on a weekly basis prior to and following the storm. Surveys conducted in the four weeks before Hurricane Sandy turned up mostly (>95%) bay anchovy, *Anchoa mitchilli,* distributed broadly and some (N=~350) blueback herring, *Alosa aestivalis*, from Newark Bay and Arthur Kill (U.S. Army Corps of Engineers). Surveys conducted in the week after the storm collected greater numbers (~1,200) of blueback herring in the Arthur Kill, Newark Bay, and Kill Van Kull as well as 800 in the Upper Bay and approximately 1,400 in the Lower Bay (U.S. Army Corps of Engineers). That survey also collected small numbers of alewife, *Alosa*

pseudoharrengus, in Kill Van Kull and Upper and Lower Bays, a few American shad, *Alosa sapidissima*, in the Upper and Lower Bays and a small number of Atlantic menhaden, *Brevoortia tyrannus*, most of them from Newark Bay (U.S. Army Corps of Engineers). These data may indicate an increased rate of fish migrating out of the rivers into the ocean, but at this time it is impossible to say whether this is related to the storm or simply to normal autumn migration movements. In 2011, Hurricane Irene did appear to affect these same fish, but the natures of these two storms are also very different (which will be discussed later). Croaker, *Micropogonias undulatus*, and blue crab, *Callinectes sapidus*, have been shown to have an increase in larval recruitment during large storms and while Sandy's late October date might have been late for blue crabs, croakers may have benefited from the event (Secor). Conversely, marine strays are not uncommon following storms and offshore species may have been located inshore following the storm. One example is that a number of oyster toadfish, *Opsanus tau,* normally found in the Bay, were observed far upriver in the days following Sandy (Mattson).

Stray birds are also common during storm events. Many water birds including dunlin, *Calidris alpine*, black scoter, *Melanitta americana*, surf scoter, *Melanitta perspicillata*, and white-wing scoter, *Melanitta deglandi*, were seen struggling to fly north up New York Harbor and the Hudson River the day before the storm. In the days after the storm more offshore species were spotted in the area, including black and white-wing scoter, northern gannet, *Morus bassanus*, parasitc jaeger, *Stercorarius parasiticus*, pomarine jaeger, *Stercorarius pomarinus*, and both Wilson's storm petrel, *Oceanites oceanicus*, and Leach's storm petrel, *Oceanodroma leucorhoa* (Hudson River Almanac). Also following the storm, brant geese, *Branta bernicla*, and a red phalarope, *Phalaropus fulicarius*, were seen flying down towards the harbor from the Hudson (Hudson River Almanac).

The Raritan Bay Slag Superfund site, which is located in Laurence Harbor on the south shore of the Bay, is contaminated with lead slag left over from metal smelting (EPA website). After the storm, EPA officials tested grounds in the vicinity of the site – two from a public playground and two from a restricted beach. Only one sample, taken from the beach was found to have lead levels above recreational standards (EPA website). Further testing will be done in the future.

Observations and assessments of the shorelines along the lower Raritan River were not made following the storm due to local damages to boats and marinas as well as the fact that shoreline properties downriver are privately owned (Mans).

Jamaica Bay, NY (Gateway National Park)

Jamaica Bay is a large estuary situated in Brooklyn and Queens. It is an important breeding area for fish and birds, but also includes residential zones as well as John F. Kennedy (JFK) International Airport. In the center of Jamaica Bay is the Wildlife Refuge of the National Park Service, which is a popular area with birders and other nature enthusiasts from the area. The Refuge features two ponds, both created by Robert Moses in 1951—the larger East Pond and the smaller West Pond. Of the two, the West Pond is more visited due to the clear walking path that surrounds it, offering the public an easily accessible view of ducks and other water birds, as well as of warblers and raptors that visit for food and fresh drinking water.

The West Pond features a valve to let in more fresh water as needed. This valve has been broken for a few years, causing the pond to become saltier as a result, but it was still nearly fresh until Sandy hit. At that time, Sandy cut channels between the estuary and the ponds (Kanonik, Riepe, Taft). The East pond has a channel 120 feet wide,

which the MTA is currently working on repairing; a second channel may have also been cut into the pond but refilled later on by the storm (Avrin). The channel cut into the West Pond is roughly 30 feet across. The result is that the previously freshwater ponds are now saltwater inlets of the Bay. While the East Pond may soon be repaired, the West Pond will take longer if repairs are made. The possible outcomes of this are numerous: changes in foraging habitats, decreased access to fresh water, and even the potential for a decrease in visitors to the park.

Sandy also had a strong effect on vegetation at the Jamaica Bay Wildlife Refuge with a number of species reported to be washed away, including bayberry, *Myrica cerifera*, and saltspray rose, *Rosa rugosa*; it is suspected that prickly pear cacti, *Opuntia humifusa*, were as well (Kanonik). In Breezy Point, bayberry along the shore was taken out (Taft). Also at Breezy Point, American beachgrass, *Ammophilia brevigulata*, was wiped out above ground, but the rhizomes survived, allowing the plants to recover (although the coverage may be sparser than before) (Taft). On the islands in the Bay, the trees and marshes appear to be minimally affected (Riepe). Saltmarsh restoration sites in the Bay were likewise unaffected (Baron, Rafferty, Weppler) although the construction and goose fencing protection of the sites was badly damaged (Baron, Weppler).

The storm also had varied effects on animal life at the Refuge. Diamondback terrapin, *Malaclemys terrapin*, are known to nest on the Bay-side beaches separating the Bay from the West Pond, and it is thought that they likely nest on the East Pond as well (Burke, Kanonik). By late October, all eggs would have hatched, but young terrapins often remain near the nest for a while after hatching, so it is possible that some were still present at the nest sites when the storm hit (Burke, Kanonik). The channel that cut through the beach likely destroyed a small number of nests (maybe 10 to 15) (Burke); however, the overall effect on their nesting habitat may be positive for two reasons. First, several steep sand dunes were leveled in the storm (Burke, Kanonik). These dunes were previously unusable as breeding habitat because they were too steep for the terrapins to climb. Their gentle gradation is now ideal for nesting. Second, the salinization of the ponds turned their shores into potential nesting habitat (Burke, Kanonik). In addition, the now saltwater ponds are potential foraging habitats (Burke). How the terrapin population itself fared in the storm is unknown and our knowledge of their habits is limited, making it difficult to estimate survival rates (Burke).

The West Pond had also been home to several snapping turtles, *Chelydra serpentine*, which were all tagged and are being monitored by local researchers (Burke, Kanonik). However, the turtles have not been observed since the storm (Burke, Kanonik). While they can tolerate some salinity, they cannot withstand the current saltwater conditions of the Ponds (Burke). If they did weather the storm, their continued survival would rely on their finding other sources of fresh water, but in the current low temperatures, it is uncertain how far they can travel. Other herps in the area, including redbacked salamander, *Plethodon cinereus*, and gray tee frog, *Hyla versicolor*, are also reliant on fresh water (Burke).

Jamaica Bay is also an important nesting site for horseshoe crab, *Limulus polyphemus*, with spawning grounds at Plumb Beach, Big Egg and Dead Horse Bay. How the storm may have affected their breeding success will depend on exactly how these areas were affected. Beach erosion would decrease the amount of breeding grounds available but sand deposition may or may not increase it (Sclafani). Grain size, slope and elevation are all important factors for horseshoe crabs selection breeding areas (Sclafani). Observations of flattened dunes (Kanonik) could indicate a beneficial effect from the storm. Alternatively, if sand was deposited on any of the nesting areas, its effect on the crabs could depend on the grain size of the sediments (Sclafani).

Some breeding habitats for birds in Jamaica Bay were affected, in particular for shore-nesting birds like piping plover, *Charadrius melodus*, and black skimmer, *Rhynchops niger*, both of which are known to nest on Breezy Point (Burke, Kanonik, Taft). It is uncertain whether damage to their nesting beaches will affect their

breeding success; however, the possible thinning of beach grass in these areas may prove beneficial (Taft). In addition, many shore birds, including piping plover like overwashed areas (Sclafani). Many species nest in trees, and while individual trees were knocked down, plenty remain standing, providing those birds nesting habitat come spring (Taft). Geese, cormorants, gulls, and wading birds all nest on islands within the Bay; with little damage reported to these islands, it is unlikely the storm will have much of an effect on their breeding success. There was some concern and speculation about the fate of small mammals in the affected areas around the Bay (Taft), but the only mention of known effects to mammals was a second-hand report that a number of rabbits around JFK Airport were found dead (Kanonik). Although harriers, *Circus cyaneus*, and Cooper's hawk, *Accipiter cooperi*, were observed in the Refuge a few days after the storm (Taft), a significant decrease in the rodent population, if such occurred, could prompt these birds and other predators to leave the area, at least temporarily.

Staten Island, NY

Of the areas discussed in the surveys, the east side of Staten Island was the most affected by Sandy. That area experienced the full force of both the winds and the tidal swelling. Human structures up and down the coast were destroyed and there is evidence that much of the coastal habitats were greatly affected as well. Sand was pushed inland up to 60 feet from the shore—in one spot, up to about 150 feet inland—and much of the nearshore understory was covered up to three inches deep in sand (Wollney). Mats of *Phragmites australis* were also washed inwards, smothering understory plants up to 300 to 400 feet from the shore, and were even found in tree branches 10 feet up (Wollney). In some places, the local topography was affected by the storm. For example, one bluff at Great Kills, reaching 10 to 12 feet high, was flattened into a gradual slope (Summers, Taft, Wollney). The bluff served as nesting habitat for belted kingfisher, *Megaceryle alcyon*, bank swallow, *Riparia riparia*, and cliff swallow, *Petrochelidon pyrrhonota* (Summers, Wollney). Without the steep face, it is now unsuitable for those species. The only marine species reported as being found dead was a mantis shrimp, *Squalla empusa*, in Conference House Park on Staten Island (Wollney).

The west side of Staten Island also experienced flooding, but relatively little wind damage. The shores showed some erosion, with sizable sections of shoreline carved out by water in locations (Summers). Prall's Island, in the Arthur Kill, showed signs that it had been completely overwashed by the tide, with the exception of the shale hills on the north end (Elbin, Summers). Wrack and debris, which previously covered the edges of the island, can now be found in the middle of the island—evidence of the overwash (Summers). The *Phragmites* marshes on the coasts of the island were left cleaner than before (Summers). Prall's was once the site of a wading bird colony and the Parks Department is currently working in one area of the island to grow vegetation conducive to heron nesting, in the hopes for a return of the colony. In addition to flood damage (Larson, Summers), the protective fencing surrounding this area was knocked down, allowing the island's deer population to browse freely (Summers).

The salt marshes of Prall's Island, as well as those on the west shore of Staten Island, were covered in an oil slick (Elbin, Summers). During the storm, there were three separate oil spills in the area (Alderson, Sheehan) which are still under investigation at the time of this writing. What effect the oil will have is unknown, but there is concern about its potential impact on local wildlife. On Prall's Island, a dead mourning dove, *Zenaica*

macroura, was found in the oil slick, but the cause of death is unknown (Summers). A double-crested cormorant, *Phalacrocorax auritus*, was found dead by NYS DEC in the area (Elbin). Several other birds were also found covered in oil and brought to the Bronx Zoo and to Volunteers for Wildlife, a wildlife rehabilitation facility on Staten Island (Howley-Newcomb, Drew). Of those brought to the Volunteers for Wildlife, two were mute swans, *Cygnus olor*, and four were mallard ducks, *Anas platyrhinchos* (Drew).

Saw Mill Creek on Staten Island was flooded, with evidence that the water covered a good portion of the tree trunks (Summers). Fresh Kills also showed signs of flooding, mainly from the leftover debris extending up to 20 feet from the banks, which was made up of approximately 40% human garbage and 60% *Phragmites* stalks (Hirsh). While some trees were down in the area, the damage was generally minimal, aside from the debris covering the ground along the waterway (Hirsh).

Other inland locations on Staten Island also showed damage, and while our survey was focused more on the waterways and shorelines, some survey respondents commented on damage to terrestrial habitats. Trees were knocked down throughout the island, including a variety of tree species. On Staten Island, as well as throughout the region, callery pear, *Pryus calleryana*, seemed to be exceptionally vulnerable to wind damage (Summers, Wollney). It is possible that the saltwater inundation will have a harmful effect on plant life, but it is still too early to know what kind of damage may result. There were also reports of areas which were still flooded in seawater several days after the storm, which increases the chances that trees in those areas will have to be taken down in the future (Summers).

Brown's Pond, at Mount Loretto, was found surrounded by dead fish, mostly carp, *Cyprinus carpio*. The cause of the kill is unknown but is likely due to the sudden increase in salinity. A number of small freshwater ponds near the shores on the east side of the island were also almost certainly overwashed by the tide due to their low elevation and proximities to the coast (Wollney). However, at the time of the interviews, none of the respondents had been able to check on them. In addition to the effects on freshwater fish, the flooding could also impact other species which rely on the ponds. A new and as yet unnamed species of leopard frog in the area was one species that could have been affected in this way (Feinberg, Kiviat). Its salinity tolerance is unknown but it is believed to be able to survive salinity concentrations of one part per thousand (Kiviat). All known locations of the species on Staten Island were in the flood zone (Feinberg). In addition, at that time of year, the frogs were probably still active although no longer breeding (Feinberg). The species population is small as is its range, meaning the potential impact of Sandy could be devastating (Feinberg). By the time of this writing, the frogs would likely be hibernating so a formal check on the population will have to wait until around March 2013 (Feinberg).

Sandy Hook, NJ

Sandy Hook, NJ, was exposed to the full power of the tidal surge and the worst of the storm's winds. The shore profile was completely changed and sand dunes along the peninsula were pushed up to several hundred feet west (Alderson). Lesser storms have had similar effects on the peninsula (Weis), though Sandy is noteworthy for its power. Many dunes were completely flattened, likely causing great amounts of damage to the beach grass normally found on them and to the bird species that use them for breeding (Alderson). The holly, *Illex opaca*, and red cedar, *Juniperus virginiana*, forests in the area held up well through the storm, while the marshes in Navesink and Shrewsbury Rivers to the south had a significant amount of debris and many of the shore areas in towns in the area

were covered in sand (Alderson). Atlantic Highlands, west of Sandy Hook was also reportedly damaged but no facts about the damage were available (Shaw).

NJ Meadowlands

Flooding occurred in areas throughout the Meadowlands. Definitive damages from the storm are few but a number of suspected impacts could be significant. A 76-acre marsh appeared to have been completely flooded leaving about seven areas covered in two feet of wrack (Newhouse). Kearney Marsh – an important breeding site for least bittern, *Ixobrychus exilis* – had floating islands of *Phragmites* pushed inland and the area has become "more of a lake with surrounding *Phragmites* habitat" (Newhouse) and it is feared that at least some of the potential nesting sites have been lost (Newhouse). In addition, as in the Hackensack River, some areas reported that numerous carp had washed up on the shores (Newhouse). Data collected by the Meadowlands Environmental Research Institute showed a sharp increase in salinity in various areas of the Meadowlands as the storm hit (MERI website), supporting the hypothesis that this caused the fish kills. Several of the ponds in the area were home to the same species of leopard frog mentioned in the Staten Island section and it is believed that at least some of the ponds the species is known to occur in were flooded with brackish water (Kiviat). Finally, many of the local raptors moved out with the storm and few have returned (Newhouse). It is suspected that the rodent population decreased in the flooded areas which could affect the importance of the area to birds of prey (Newhouse).

The Hackensack River was also washed in sewage and oil (Hugh, Sheehan). Debris is also a problem, but only on the east shore where it covers acres of marsh (Hugh, Sheehan). The *Phragmites* and *Spartina alterniflora* constituting the marsh are largely intact, and their roots and rhizomes survived, indicating little real damage (Sheehan). Another effect of the storm was a fairly large fish kill on the shores (Sheehan). Most of the fish observed were carp, but many species were affected (Sheehan). The cause of the kill is unknown, but two hypothesized reasons are the sudden increase in salinity as the ocean water surged into the river, or that the fish were carried along with the surge but were then stranded when the tide water retreated (Sheehan). Other areas of the Meadowlands experienced similar fish kills, with carp being the most affected species (Newhouse). Berry's Creek which is a tributary of the Hackensack River flooded as well. Berry's Creek is a Superfund site and there was concern about the re-suspension of sediments but there was no evidence of it (Tomchuck). Overall the area showed little damage (Tomchuck); an aerial survey is planned to look for any missing mudflats or other signs of disturbance (Tomchuck).

Woodbridge Creek, NJ

The New Jersey shore west of the Arthur Kill was hit harder by oil damage than the Staten Island shore to the east, with several creeks and streams observed to have contamination; Smith Creek Inlet, Woodbridge, and Rum Creek were affected the most (corresponding with the storm's winds which were blowing westward) (Alderson, Mans). Aside from oil damage, however, the storm's overall impact on the marshes was minimal (Alderson). The greatest impact was witnessed above and beyond the tidal marshes, with the vast majority of debris being deposited well inland of them (Alderson).

Inwood Park, NY

Inwood Park had relatively little damage from the storm. A number of trees had fallen to the wind, but overall the area remained in fairly good shape (Burg). A few days after the storm white-throated sparrow, *Zonotrichia albicollis*, house sparrow, *Passer domesticus*, juncos, *Junco sp.*, downy woodpecker, *Picoides pubescens*, and white-breasted nuthatch, *Sitta carolinesnis*, were all observed (Burg). The park's location in a depression may have protected it from the worst of the winds and no evidence of flooding was observed (Burg).

Bronx River, NY

The river itself showed little impact from the storm (Griffin, Yau). A restored salt marsh in Soundview Park was estimated to have lost approximately 4,000 plants on one acre (Griffin, Larson, Weppler), but otherwise the river and its residents were not noticeably affected, and the tidal surge did not reach them (Griffin, Yau). An assessment of newly recruited oysters near Soundview Park, conducted after the storm, found similar populations and no evidence of storm induced mortality (Kalchmayr). Historically, rain events have had a bigger impact on the river, and Sandy brought only modest rainfall (Griffin, Yau). The area surrounding the river did show some wind damage, with fallen or split trees and broken branches, but no evidence of flooding (Yau). The fallen trees opened up some large holes in the canopy of the Bronx Forest, and the nearby New York Botanical Gardens reportedly lost close to 200 trees to the wind (Yau). The Parks Department generally lets the forest grow on its own, but may plant some small trees in the gaps to shade out Japanese knotweed, *Fallopia japonica*, which is a problem invasive in the area (Yau). The loss of the trees should not have a major impact on terrestrial species, although branches landing in the river can be beneficial for fish and other aquatic species (Yau). The Parks Department has been working to diversify the river habitat through the addition of large rocks and branches, and a storm like Sandy can help in this regard (Yau). American eel, *Anguilla rostrata*, have been observed to prefer areas with such environmental diversity (Yau). On the downside, branches can catch floating trash and too many of them can interfere with the recreational use of canoes and kayaks in the river (Yau).

Manmade oyster beds at Castle Hill and Soundview Parks showed little damage other than some shell displacement (Kalchmayr). Lodge also observed oyster beds in the area of the river and confirmed the lack of damage. These observations are preliminary and a full inspection of the oyster beds will be made in December 2012 (Kalchmayr, Ravit); however, the lack of disturbance to the Bronx River suggests that little damage will be found.

The Hudson River

The Hudson River showed little apparent damage from the storm. The tidal surge travelled far up the river, but aside from evidence of flooding along the banks, the river showed no turbidity or other obvious effects (Bowser, Lipscomb, Miller). Wrack was carried inland (Spector) and debris was washed ashore (Lipscomb, Strayer); one respondent even stated that the river looked better several days after the storm because all the trash had been washed ashore (Lipscomb). On shore, some vegetation on the banks may have been flattened out, but not more than is normally seen in the winter (Miller, Stanne). The same is true for various streams in the Catskills, which did not flood (Jiskra).

The storm reportedly had little to no effect on sturgeon, *Acipenser oxyrinchus*, in the river and a number of them which were sonic-tagged showed no change in location or movements during the storm (Stanne). On the other hand, a number of sonic-tagged striped bass, *Morone saxitilis*, in the river headed downriver during the storm (Secor). Those fish farther upriver appeared to do so more quickly than the rest (Secor). Striped bass normally begin their downriver migration at temperature cues and the consequent lowering of water temperatures as the tide surged in could explain this behavior (Secor). NYS DEC seined the lower Hudson a couple of weeks after the storm, the catch was typical for the time of year—low numbers and common small fish.

Conversely, marine strays are not uncommon following storms and offshore species may have been located inshore following the storm. One example are a number of oyster toadfish, normally found in the Bay, were observed far upriver in the days following Sandy, as was a smooth dogfish, *Mustelus canis* (Mattson). Aside from those exceptions, no estuarine visitors were mentioned by respondents and seining along the banks of the lower Hudson yielded nothing out of the ordinary for this time of year (Bowser).

Interestingly, salinity data collected by the Hudson River Environmental Conditions Observing System, at Piermont, saw substantial elevations in salinity with every high tide in the days leading up to the storm, beginning on October 25th (Stanne). Whether this is directly related to the approaching storm is currently undetermined, but a theory put forward was "that the approaching surge from Sandy provided enough hydrological head to push a greater volume of increasingly salty water past the sensor with each high tide" (Stanne). As for the tidal surge in the Hudson during the storm, Stanne proposed two possibilities: either sea water was pushed into the estuary and upriver or wave energy was pushed upriver with little actual transfer of water. The consequences of these are obvious as the second option introduces no salinity into the river itself. Data to support one theory or the other should be available in the future.

While there were no large oil spills in the Hudson such as those in the Arthur Kill, wastewater treatment plants in Kingston and Yonkers were flooded (Spector). The result was the release of raw sewage into the river though the amounts and the effects of these events are unclear.

Overall Pattern

Sandy had the largest effect on areas close to the Atlantic Ocean—Jamaica Bay, Sandy Hook, and Staten Island. Areas located farther upriver from the harbor saw little damage from flooding, although winds were still a factor. As this survey was primarily interested in the Hudson/Raritan estuary and its associated waterways, the impact of high winds on inland locations was not fully discussed. Areas around the harbor saw heavy flooding, carrying with it high volumes of sand, *Phragmites* wrack, and trash, which then further impacted inshore communities by covering understory plants in thick layers of debris. Even Fresh Kills Park, on the western interior of Staten Island, was covered with so much debris that it is estimated that heavy machinery will be required to remove all of it (Hirsh).

Farther north, reports from the Bronx River, the Hudson River and the Catskills all indicated little to no damage to the waterways. Flooding was reported from the banks of the Hudson only, and does not appear to have been as great as that seen in New York City, with minimal damage to the shorelines (Lipscomb, Miller). Although no respondents reported wind damage around the Hudson during the survey, it was mentioned in

regard to the forest surrounding the Bronx River (Yau), and therefore, it may be that some wind damage occurred in the vicinity of the Hudson as well.

In general, most observed damage was above the tide lines, and was primarily due to winds or flooding from the tide. In part this may be due to limitations in individual's abilities to observe and/or monitor these environments in autumn. As a result, most of the statements made about marine species were educated guesses. Species living well under the surface of the water, such as fishes, oysters, and eelgrass, would be relatively immune to both winds and flooding, and preliminary reports suggest that they were spared from major impacts. It is possible that some intertidal marine communities were affected by either the tidal surge or the floating debris, but it is difficult to say for sure if the dead organisms sunk into subtidal areas. Fresh or brackish water species, however, may have been more vulnerable, especially given the sudden increase in salinity. The fish kills in the Meadowlands, the Hackensack River and at Brown's Pond on Staten Island for example, could possibly be attributed to this, although they may also be due to the fish being stranded as the water retreated. Fish are often found along the shores following a storm, but the great numbers observed in the kill following Sandy seem like more than normal for such an event. The data from the U.S. Army Corps of Engineers may also indicate an effect on young migratory fish in the harbor, but the data are not conclusive.

Hurricane Irene, which hit the area of study in late August 2011, was a very different storm compared to Sandy, and as such, makes an interesting comparison. Like Sandy, Irene brought high winds. Unlike Sandy, Irene also brought heavy rains, causing flooding but not the extreme tidal swelling of Sandy. As a result, Irene had a huge impact on the Hudson and Bronx Rivers (Bowser, Burke, Griffin, Lipscomb, Mattson, Yau), but relatively little impact on Staten Island and Jamaica Bay. Both the Hudson and Bronx Rivers experienced heavy flooding during Irene, along with decreased salinity and increased turbidity that lasted for several weeks (Burke, Lispcomb). Irene brought flooding over 14 feet above normal to the area of the Hudson around Albany and flooding comparable to Sandy about ten miles downriver from that (USGS website). Farther downriver, Irene did not flood the banks as much as Sandy (USGS website) but had a more noticeable impact to the river itself. The suspended sediment covered vegetation during the flooding and remained behind afterwards. In addition, Irene scoured the bottom of the Hudson, washing away much of the subaquatic vegetation growing there (Lipscomb, Spector). The effects of Sandy in comparison were short lived: Sandy swelled the Hudson with tidewaters, increasing salinity and possibly the turbidity as well, but these effects ended as the tide retreated, rather than lasting for weeks, as was the case with Irene. An interesting note on Irene came from Berry's Creek, NJ which flooded during Irene. Afterwards, more water was recorded leaving the Creek than the rainfall could account for – and it is believed that some of the flood water may have entered the Creek through an unknown alternate route from another body of water such as the Hackensack River (Tomchuck).

Two separate studies seining for fish after Irene found juvenile herring that were thought to be significantly farther south than normal for that time of year (Bowser, U.S. Army Corps of Engineers), though late October is a time for their outmigration. Fish counts in the Hudson were low overall following Irene but what aspect of Irene was responsible—if Irene was responsible—is unknown. Oysters—both manmade and natural reefs—suffered high mortality in Irene, while they appear to be largely unaffected by Sandy (Kalchmayr). In Jamaica Bay, Irene damaged shores and potential nesting habitat for diamondback terrapin and other species, while during Sandy, damage to these habitats seemed to be minimal, and the deposition of sand may have even increased the amount of habitat. One exception could be horseshoe crabs which had a good breeding year in 2012 following Irene (Sclafani). Whether that success was related to Irene is unknown and may be qualified by the fact that 2011 was also a very successful breeding year (Sclafani). Menhaden and bluefish, *Pomatomus saltatrix*, were also reported to be abundant in 2012 (Griffin). On Staten Island, Wolfe's Pond was breached

during Irene and was probably either breached or overwashed in Sandy as well (Wollney). Sandy generally left behind more debris in the harbor area, while, in general, little was said about debris from Irene. To understand the effects of powerful storm events on natural systems, it is important to understand the natures of the storms in question. Both Irene and Sandy were classified as hurricanes, but their presentations were very different as were their impacts.

On land, deer were reported as being a common sight in Staten Island in the days after the storm (Hirsh, Summers, Wollney) while at least a few hunters in the Catskills had reportedly little luck finding any during the same period (Jiskra). Whether these observations represent real trends and whether any trends are due to the storm cannot be answered. Downed trees could mean reduced breeding habitat for birds, but plenty of trees remain. Overwashed beaches may well be beneficial for the terrapin population as well as for many of the invertebrates, and birds that depend on them for breeding. In general, the effect on other wildlife remains largely open and may not be known until the spring breeding season when many species return to the affected areas.

The Human Element

Much of the damage caused by Sandy came from wind and flooding, but the effects of human civilization on natural systems during and following the storm cannot be ignored. Debris in the form of garbage of all kinds was nearly universal on the shores of all areas that flooded in the storm. Some pieces of debris were noteworthy for their size, such as a shipping container, which washed up on the shores of the Wildlife Refuge in Jamaica Bay, or the roofs of houses that were carried far from their origins, but most were smaller and could be characterized as little more than trash. The impact of this trash on coastal communities is debatable. It is an ugly sight for humans and some trash can be hazardous or toxic to wildlife, but some can turn out to be useful to wildlife as hiding places or nesting material. Regardless of its impact, clean-up can be expensive and time consuming.

Little debris was found in the water following the storm and the water may have been cleaned of debris by the storm. One hypothesized explanation was that the high winds drove all the debris off the water's surface and onto the shores. Evidence for this lies in the fact that large wood timbers remained in the water. These pieces of wood float in the water with very little surface area exposed to the wind and so their movement would be more likely due to water flow than wind. The one exception observed was the Gowanus Canal, which was dirtier than normal. The reason proposed was that when the tides rose and flowed out onto the ground around the canal, it picked up a lot of debris and oil. When the tide retreated, it carried these back into the canal where its small size concentrated the waste. Larger, well-mixed bodies of water may have received waste in the same way but the effect would not be as noticeable.

The oil spills in the Arthur Kill will have a large long-term impact on that area. The spills are still under investigation and final decisions on causes and impacts cannot be given yet. It is certain that oil covering salt marshes throughout the area will have an effect on both the plants making up the marshes and all the animals which rely on them. Oil slicks in the water indicate that fish and other species in the water column will be affected as well. Several birds covered in oil were brought into rehabilitation centers following the storm; those taken in by the Volunteers for Wildlife facility were all expected to survive. A dead oil-coated double-crested cormorant picked up by NYSDEC under the Outerbridge Crossing was not so lucky.

In addition to oil, other chemicals were also released into the water. Two of the birds brought into the Volunteers for Wildlife facility were covered in home heating oil. In addition, a number of gas tanks of varying sizes washed up on the shores of Jamaica Bay (Kanonik) and the Hudson River (Spector). These tanks were

intact when found, but their discovery could indicate that others were also cast adrift in the storm, and it is possible that some were damaged in the process, releasing gas. In addition, it is possible that fuel tanks, even if not dislocated by the storm, may have damaged by floating debris, causing leaks. Some buried pipes near the Hudson were ruptured in this fashion, so the danger is real (Spector). Whether from isolated tanks, factories or other sources, the DEC identified around 400 toxic releases in Region Three (mainstem Hudson region), many of which were on the Hudson River (Spector).

Sewage discharges during heavy rain events are fairly common in large cities like New York. While there was not much rain, the tidal surge could have the same effect as heavy rains causing sewer overflows. In addition, failures or damages to treatment plants could further impact the ability of the local wastewater systems to prevent the escape of raw sewage into the waterways. The impact of high volumes of the various bacteria associated with human waste and chemicals flushed through the sewers on a daily basis can add stress to systems already stressed out by high-impact weather events. Interestingly, of the five sites sampled by Riverkeeper in and around the harbor on November 2, three days after the storm, only two – Gowanus Canal and Newtown Creek by the Metropolitan Bridge – showed "unacceptable" levels of *Enterococcus* bacteria in the water (Friedman). Of those, the Newtown Creek location still had a lower population (171 colonies per sample) than it had showed when sampled on October 10, before the storm (Friedman). The Gowanus Canal sample on the other hand had over 24,200 colonies than the last sample – roughly 93 times higher, and 230 times the threshold where you would close the water to swimmers (Friedman). Having such high numbers several days after the storm could indicate the continuing release of sewage into the Canal, and is similar to the contamination seen after major rainstorms or when intake pumps or pipes break causing the release of raw sewage (Friedman). The exact source of the contamination was unknown but may have been to hurricane damage to sewage treatment infrastructure (Friedman). Of the other sites, the Battery midchannel and East River midchannel (at 23rd street) locations showed only small increases which put them in the "elevated risk" category. The last site at Dutch Kills in Newtown Creek showed a remarkable drop from 2,333 to 10 colonies per sample (Friedman). In general, the data collected suggests that "…if there was widespread sewage contamination following the hurricane, conditions were reverting back to normal. Unfortunately, for some locations, normal conditions are contaminated" (Friedman).

As with the Hudson, a number of wastewater treatment plants in New Jersey were flooded or otherwise damaged during the storm, causing billions of gallons of raw sewage to be released into surrounding waters (Mans). In particular the plant in Sayreville, NJ was offline letting approximately 750 million gallons of raw sewage into the Raritan Bay before it was running again on November 15, 2012 (Mans). A second plant off the Passaic River was only brought back online in late November (Mans). Part of the delay was due to the decimation of the plant's bacterial colony which took time to regrow. The sewage released by the plant would find its way down the Passaic River, and come out in Newark Bay before finally being released in New York Harbor. Testing by NY/NJ Riverkeeper has shown that fecal coliform levels were returning to normal by early December (Mans). At the time of this writing, many of the affected wastewater treatment plants were back online or working to get online.

Pollutants could also be introduced to the system by the receding floodwaters as was seen in Gowanus Canal. Several areas flooded on the banks of the Hudson were heavily polluted from former activities. Some of these had been remediated, others not. Many of these former industrial sites contain high levels of heavy metals. For example, Brown's Field in Poughkeepsie, NY is an un-remediated former lumber yard which is heavily polluted with arsenic (Spector). It flooded during the storm, potentially releasing that arsenic into the river (Spector). Many of these sites have been flooded three times in recent history, each time potentially

releasing toxins. What effect these areas might have on the river is still a question but Marist College collected sediment samples from several soon after the storm (Spector), so an answer may be forthcoming.

Another source of pollution that many respondents expressed concern over is the possible stirring up of sediments by the tide, releasing any pollutants contained within back into the water column. Pollutant-wise, the most contaminated deposits relate to conditions in the early to mid-twentieth century and lie several inches to several feet below the surface. The re-suspension of these deposits could release and redistribute toxic materials. The large volumes of sand deposited on beaches in Jamaica Bay, Sandy Hook and Staten Island indicate that Sandy did stir up some sediments in the lower harbor, but whether the same was true in the upper harbor or elsewhere is not known.

In the case of Irene, the influx of rainwater had the effect of diluting pollutants (Lipscomb), and it is possible that Sandy may show the same pattern. In the month after Irene hit, for example, water samples from the harbor showed no issues, but pollutant concentrations rose again in October. Water testing by the Hudson Riverkeeper following Sandy on November 2, 2012, showed pollutants were down from their levels at the last testing on October 10. Combined sewer overflows could also have released pathogens, though there are no reports of associated disease outbreaks.

Cleanup efforts have their own impact. In the aftermath of Sandy, sanitation crews were scrambling to clean up affected communities as fast as possible so that power could be turned on, public transportation could resume, and communities could begin to recover. In the process of the cleanup, garbage was sometimes dumped in parking lots adjacent to natural areas. These dumps are quite large and it is unknown how long they will remain in place. In the meantime, they can attract a variety of animals. The garbage dump taking up the parking lot in Reese Park (in Far Rockaway) has attracted cats and dogs and both herring gull, *Larus smithsonius*, and ring-billed gull, *Larus delawarensis*. Other species such as Norway rat, *Rattus norvegicus*, oppossums, *Didelphus virginaina*, and raccoon, *Procyon lotor*, have not yet been reported, but are likely to show up in time. At the moment, the impact of these species is limited, but come breeding season, there is concern that their increasing population density may elevate the risk to species nesting on nearby shores such as terrapins and piping plovers.

In addition to the garbage piles, the activity involved in cleanup and rebuilding efforts may also disturb wildlife. After Hurricane Irene, residents of the Catskills responded to the flooding by dredging and channeling the streams, needlessly disturbing and damaging important habitat for a variety of wildlife. A similar response is unlikely following Sandy, as that same area experienced no flooding, but it is a reminder that the efforts of individuals to mitigate damages from storms might have major impacts on wildlife and habitats.

Breezy Point was badly damaged in the storm, including the boardwalk and houses near the beach. Removal of debris will take some time and rebuilding damaged structures will take even longer. The work will still be under way in the spring when birds like piping plover and black skimmer return to the shores nearby to breed. The impact of increased human activity in close proximity to their nests may be stressful for the birds. There may be steps that construction crews can take to minimize the disturbance, but their willingness to comply and the public's tolerance for anything that slows down rebuilding of homes may be low. Similar activities elsewhere in the area may also have impacts on wildlife, and researchers and managers should keep an eye out for future potential conflicts.

Plans for Cleanup

It is common opinion that the natural systems will recover from the hurricane on their own. Few people interviewed knew of any definite plans for cleaning or mitigating the effects of the storm. Harrier Meadow

Marsh in the Meadowlands has already been cleaned up of wrack in accessible areas but additional cleanup and the planting of tree in the marsh might require additional funding (Newhouse). Few people interviewed knew of any definite plans for cleaning or mitigating the effects of the storm. Limited funds and manpower mean that any plans need to be carefully considered before action is taken. Agencies such as the National Parks Service and NYC Parks are discussing the matter and their decisions will be reached soon. Basic cleanup of many areas is already under way on a limited basis. The annual volunteer-based Earth Day cleanup of Jamaica Bay will take place again in 2013 but will probably be bigger. Many areas will need additional help in the form of funding, manpower, or even heavy machinery to effectively clean up debris. Large and heavy pieces, such as some of the large fuel containers and abandoned boats in Jamaica Bay, will require the latter, but even the smaller debris will require money to pay for dumpsters for the great volumes that will be picked up. Plans for the cleanup of the Arthur Kill have not been announced yet and may be delayed pending the results of the investigation.

When asked what they would like to see done if funding were provided, there was a wide variety of answers from respondents, but a few answers were common. The most popular answer was to restore damaged salt marshes or to build new ones. The importance of salt marshes in mitigating flooding is generally acknowledged – and was attributed to the lack of major damage to Berry's Creek (Tomchuck) – although the marshes' role in cleaning up pollution and their importance as habitat for wildlife cannot be overrstated either. How much damage the marshes sustained, however, is still an open question. The restored marshes in Jamaica Bay showed little damage or erosion, while the deep mat of *Phragmites* stalks washed up in Fresh Kills Park would seem to indicate more serious damage. No damage to roots or rhizomes was reported, however, and recovery may be quick. Of bigger concern in the Arthur Kill is the oil which is covering large portions of the marsh. How the marshes are affected by the spills will depend in part on is the extent of the damage and how long it takes to be cleaned up. A number of respondents also mentioned the value of expanding high marshes, soft shores, and oyster reefs, of which there are few in the area.

The fate of the ponds at the Wildlife Refuge in Jamaica Bay was also a common concern. Because the ponds are manmade, some people are content to leave them as they are, letting nature take its course. The vast majority of those interviewed expressed a strong desire to see the ponds—or at least the West Pond—restored to its pre-storm state. As an important source of fresh water, the West Pond attracts large numbers and varieties of birds to the Refuge, which, in turn, bring large numbers of visitors. This would be a big task, involving resealing the channel, draining the water out of the pond, and fixing the valve, before refilling it with fresh water—therefore, if the National Parks Service decides to fix the Pond, it may take a long time, and considerable resources, to complete the project.

The last common response was a hope that, in the wake of Sandy, more funding becomes available for both research and discussions on the local environment. Research in the form of monitoring populations and habitats is a necessary part of properly managing them. Furthermore, without good baseline research, the impact of events like Sandy will remain a question. In addition to research, there was interest in discussion among the scientific community and between researchers, parks staff, and politicians. Among the issues of interest that could be discussed were prioritizing areas for restoration and continuing to make politicians aware of the important environmental lessons learned from Sandy, Irene, and other such events.

A less common response, but no less important alluded to the problems inherent in the current wastewater treatment infrastructure. Problems were reported around the estuary, in the Passaic and East Rivers and far up the Hudson River. While the storm had a noticeable effect on wastewater treatment plants, causing flooding and other damage that inhibited or completely stopped all treatment, similar problems, large storms are not required for such contamination to occur and contamination on the scales seen during Sandy are

a lot more common than most of us realize. As Robert Friedman of the Riverkeeper put it, “It’s not necessarily because of big events like Sandy, it happens all the time. Because this type of sewage contamination is common, it really should be more of a concern than the concern we are seeing now about sewage contamination following a big, rare event, like a direct hit from a hurricane.”

Conclusions

We did not detect any major effects of Hurricane Sandy on any specific wildlife or plant species. Fish are difficult to assess given their underwater habitat and high mobility. There was no evidence found of harm to marine fish species, nor to diadromous forms. The few fish found dead seemed mainly to be freshwater species in ponds exposed to fatal salinity levels. We did learn of disturbances to particular habitats, such as substantial trash and wrack wash-up on islands in the Arthur Kill, salinization of brackish water ponds in Jamaica Bay and Staten Island, and changes in island morphology in Jamaica Bay. Not all habitat change is negative though, what may impinge on one set of species may assist others. Another factor is whether habitat alteration due to Sandy is actively remediated or whether such habitats are allowed to evolve from their new states. A perhaps greater concern is whether there were longer term, more broad reaching effects from sediment remobilization of contaminants and from high levels of raw sewage discharge (both of which are beyond the scope of this assessement).

Hurricane Sandy was an unusual weather event for the New York City area. Hurricanes rarely make landfall so close to the city but this one was especially significant and damaging due to its merging with another storm and its coming ashore during a spring tide. While events like this one have been rare, the damage caused by Sandy is a reminder that we cannot grow complacent in their absence. Natural systems can recover from natural events but the stresses put on these systems can render them vulnerable in a way they may not have been before. In addition, impacts from the human environment can make the damage worse than it would be normally. For example, the oil covering much of the Arthur Kill made a bad situation much worse. In general, it is important to remember that normal levels in the harbor and its surroundings are far from pristine (Freidman, Lipscomb, Weiss) and cleaning up out natural areas in general can help these systems deal with natural disasters.

One potential benefit of the storm is that it may have increased awareness in the public on the benefits of natural systems such as salt marshes to moderate flooding. This has the potential to encourage policy makers to support programs aimed at restoring and expanding marshes, oyster beds and other beneficial features. At the same time, advocates for the environment need to be careful not to overstate the importance of these systems. Salt marshes may help reduce flood damage to communities but they do not guarantee that future storms will not flood low areas at all. There are plenty of benefits to restoring these systems and our best hope in doing so lies in keeping public awareness of them alive.

As global warming raises temperatures, weather systems will change. Hurricane Sandy may have been an unusual event but severe weather could become more frequent. Most weather models predict that on a worldwide basis, hurricanes will decrease in frequency but increase in severity. If we ignore the lessons learned in Sandy and Irene we could find ourselves facing worse damage the next time around. Similarly, as sea levels rise, flood events will become more common. The flooding of Sandy was unusual but a glimpse at some of the areas that are vulnerable in the future.

This assessment covered the Hudson-Raritan estuary and the various tributaries leading into it, as well as surrounding areas; however, it is only one of several being conducted throughout the east coast. For a

complete picture of the impact of Sandy, reviewing and analyzing the other reports will be necessary. The assessment was conducted over the course of course of a week soon after the hurricane. As such, many effects of the storm were as yet unknown or only suspected. In addition, many of those interviewed had not had a chance to go out into the field to personally survey the damages. In contrast, others were so busy in the aftermath that they were for all intents and purposes unreachable. Those who were reached were all very helpful and eager to share information, even if their knowledge was limited.

It was also with great care that both the respondents and the investigators avoided making general characterizations based on individual observations; they were also cautious not to overstate trends or impacts. For example, wildlife rehabilitators often receive squirrels and other arboreal species which have fallen to the ground after storms, and birds usually occurring far offshore are sometimes driven to land by storms. These are effects on individuals, however, and tell us little about the effect on overall populations. Spotting members of a species after the storm is no indication that the species was unaffected, while their absence does not necessarily indicate harm. In the days after the storm, harriers and Cooper's hawks were seen in Jamaica Bay (Taft); juncos, downy woodpecker; and white-throated sparrow in Inwood Park (Burg); and monarch, *Danaus plexippus*, and angle-wing butterflies, *Polygonia sp.*, and a green darner dragonfly, *Anax junius*, were all spotted in affected areas of Staten Island (Wollney). Does their presence mean anything? That won't be known until the scientific community has a chance to do more rigorous surveys. Aquatic life is still difficult to observe. The dead fish in the Meadowlands and in Brown's Pond were obvious because they were washed up on the shore in great numbers. Other large fish kills were not reported and likely did not occur. A dead mantis shrimp found in Conference House Park on Staten Island is the only known marine casualty brought to light during the interviews. As with more terrestrial species, the true effect on marine and aquatic species will likely be a mystery, unless and until more vigorous monitoring is done. For fish like striped bass and menhaden, this will likely happen, but for many other species, likely not.

Obtaining quantification of damages was often a problem as nearly all respondents were uncomfortable estimating damages on an ordinal scale. There were a few reasons given: they had not obtained a good enough view of the area, they did not have enough of a baseline from before the storm to compare the damage to, or it was too soon after the storm to properly assess the level of damage. In addition, estimates of damage varied based on the perceptions of the respondents. For example, one person might rate the amount of sewage in the water as a ten because the water seems so much dirtier than normal, but another might rate it a one because normal levels of pollutants are worse than what they observed after the storm.

Those interviewed were also very careful to be clear about which observations they had witnessed firsthand and which they had heard about from others. For example, one respondent mentioned that 2,000 trees were knocked down citywide but that same person questioned the figure's accuracy because many estimates had been made in the weeks following the storm making it even harder than normal to judge any one report. Very often accounts overlapped and information heard secondhand by one person was often verified by another individual who had witnessed it firsthand. Individuals were also very helpful in providing names and contact information for others who would also be helpful.

In the end, this report was only possible because of the help and support of the many people we interviewed. Their care and diligence in observing and managing the local ecosystems are the first line of defense in our efforts to understand and work with nature, a role that comes to the fore-front of our consciousness when events like Hurricane Sandy come along and challenge our sense of place.

Appendix I - Questions for Hudson-Raritan Sandy RAP

(1) Are you aware of any definite effects from Hurricane Sandy on any animal or plant species in an area in which you have jurisdiction or are intimately familiar with? If so, is this based on your own observations? If not, what is the source of your information? What is the nature of the impact?

On a 10 point scale (1 being no damage and 10 being catastrophic damage) please rate the severity of the damage.

Can you estimate the extent of the damage? Please provide a quantitative estimate if possible (acreage or % of habitat loss).

(2) Concerning these same areas, do you strongly suspect any significant effects on animal or plant species, even if they are to date still undocumented? Will documentation be pursued? (Pursue for each species mentioned).

(3) If significant effects are known to have occurred, are there plans in place or being developed to remediate the effects?

(4) If effects are known and no mitigation is planned, perhaps due to limited resources, is there anything you would like to see occur if funding was provided?

(5) Concerning your area of jurisdiction or interest, are you aware of others we should speak with? (Take names and phone numbers)

(6) Beyond your area of jurisdiction or interest, are you aware of significant effects by Sandy on species in other areas and do you have suggestions on whom to speak with? (Take names and phone numbers)

(7) Do you have photographs? Do we have your permission to post the photos to the CRSSA website.

(8) Is there any related information from Hurricane Irene you'd like to mention?

Appendix II - Individuals interviewed

Carl Alderson, National Oceanic and Atmospheric Administration

Francisco Artigus, Meadowlands Environmental Research Institute

David Avrin, National Parks Service

Lisa Baron, US Army Corps of Engineers

Kate Boicourt, U.S. Environmental Protection Agency

Chris Bowser, New York State Department of Environmental Conservation

David Burg, Wild Metro

Russell Burke, Hofstra University

Bart Chezar, Independent Consultant

Hugh Carola, Hackensack Riverkeeper

Dave Davis, HDR Consultants

Jessica Drew, Volunteers For Wildlife

Susan Elbin, New York City Audubon

Jeremy Feinberg, Rutgers University

Robert Friedman, Riverkeeper

Damian Griffin, Bronx River Alliance

Eloise Hirsh, New York City Parks

Andrea Howley-Newcomb, Tristate Bird Rescue

Don Jiskra, Trout Unlimited

Kerstin Kalchmayr, NY/NJ Baykeeper

Alex Kanonik, Queens College

Erik Kiviat, Bard College & Hudsonia

Marit Larson, New York City Department of Parks

John Lipscomb, Hudson Riverkeeper

Debbie Mans, NY/NJ Baykeeper

Mark Mattson, Normandeau Associates, Inc.

Dan Miller, Hudson River National Research Reserve

Tanya Mitchell, Environmental Protection Agency

Mike Newhouse, New Jersey Meadowlands Commission

Gregory O'Mullan, Queens College

Patricia Raffety, National Parks Service

Beth Ravit, Rutgers University

Don Riepe, American Littoral Society

Matt Sclafani, Cornell University

David Secor, University of Maryland

Judy Shaw, Rutgers University

Bill Sheehan, Hackensack Riverkeeper

Sascha Spector, Scenic Hudson

Steve Stanne, New York State Department of Environmental Conservation

David Strayer, Cary Institute

Alex Summers, New York City Department of Parks

Dave Taft, National Parks Service

Doug Tomchuck, U.S. Environmental Protection Agency

Nellie Tsipoura, New Jersey Audubon

Gary Wall, U.S. Geological Survey

Judith Weis, Rutgers University

Pete Weppler, U.S. Army Corps of Engineers

Seth Wollney, Staten Island Museum

Ferdie Yau, New York City Department of Parks

David Yozzo, HDR Consultants

EPA website http://www.epa.gov/region02/superfund/npl/raritanbayslag/rbs_sandysampling.pdf

MERI website http://meriems.njmeadowlands.gov/vdv/VV_Frame.php?r=27877

NOAA website http://water.weather.gov/ahps2/crests.php?wfo=okx&gage=batn

U.S. Army Corps of Engineers – New York District Migratory Finfish Survey preliminary data Oct-Nov 2012

USGS website http://ny.water.usgs.gov/sandyindex.html

graph of flood heights http://ny.water.usgs.gov/flood/HudsonSandy.JPG

map of flooding http://54.243.149.253/home/webmap/viewer.html?webmap=c07fae08c20c4117bdb8e92e3239837e

Appendix III: Possible Restoration Projects in the Hudson-Raritan Region

As part of the rapid response survey we asked respondents if they knew of any planned mitigation for damages from the storm. While major storm damages with potentially long lasting impacts were reported (oil spills in the Arthur Kill, wastewater treatment plans failures in the Passaic, Jamaica Bay and the Hudson River etc.) the extent of the damage and the scope of any required mitigation has not yet been identified. Survey respondents were also asked if they had suggestions for restoration projects to improve impacted environments. The following project ideas are based on information provided to us in the surveys and in follow-up conversations with regional stakeholders.

(1) Stream Restoration in the Hudson Valley Watershed and Lower New York State

This concept is being presented as a result of the interest by National Fish & Wildlife Foundation in diadromous fish restoration opportunities and its call as part of this RAP assessment for action items. Below is adapted from a statement of concern from November 14, 2012, to the Hudson River Estuarine Management Advisory Committee by John Waldman, the Chair of the Fisheries Subcommittee and from a workshop on river herring restoration held at Hudson River Foundation on October 23, 2012, titled Bight *of Herring* – New York Region River Herring Restoration Workshop (see http://www.hudsonriver.org/download/herring12/herring12.pdf).

The Hudson watershed has more than 800 dams, many of which serve little or no benefit but which harm the biological functioning of rivers and streams while persisting through sheer inertia; many more are found on Long Island and New York City. Despite a growing national dam removal movement, dams of little or no value are not yet being removed in the Hudson Valley watershed and only rarely in the remainder of New York. Moreover, for streams that have dams that retain societal value, there is not yet any fish passage program.

The primary presentations on Hudson valley dams were by (1) the NOAA Restoration Center (http://www.hudsonriver.org/download/herring12/AldersonRosman.pdf) which focused on first dams in tributaries that blocked river herring and (2) The Nature Conservancy (http://www.hudsonriver.org/download/herring12/peck.ppsx) which is working on dams and culverts throughout the entire tidal Hudson watershed. There also was consideration of opportunities within New York City (accessible at http://www.hudsonriver.org/download/herring12/herring12.pdf) such as on the Hutchinson River and on Long Island (also at http://www.hudsonriver.org/download/herring12/herring12.pdf) where a small working group has made some progress.

A focused Hudson Valley and lower New York stream restoration program would offer at least three major ecological benefits:

(1) *Fundamental Ecological Integrity* – Each dam, whether the first above tidewater or any number upstream beyond that, segments its river, essentially creating a shorter reach that functions ecologically as an "island." Because of this, each species has more discrete populations but of smaller sizes, risking localized extirpations, instead of a larger, more robust population. Not only does this reduce biodiversity but it also reduces the annual phenological movements of fish and other animals that normally occur within a stream due to seasonal effects.
(2) *Diadromous and Potamodromous Fishes* – Alewife, blueback herring, American shad, and American eel are all in notable decline. Other purely riverine species such as smallmouth bass also migrate from the mainstem Hudson to spawn in tributaries. Recent regulation changes will reduce or eliminate harvests

of river herring and shad. But there also is a need and opportunity to increase production by creating or improving passage past Hudson River and other New York watershed dams.

(3) *Water Quality in the Face of Climate Change* – Dams foster increased tributary temperatures by impounding water and exposing more of it to atmospheric heating. Removing dams on tributaries is one of the few pro-active measures that can directly combat warming in the mainstem Hudson River.

There are many models in the states that have successful dam removal and fish passage programs. Some are more NGO-based, others agency led, and all involve partnerships at many levels. But a commonality is that they view the issue broadly and of high priority, having staff fully dedicated only to stream restoration, something still lacking for the Hudson Valley and elsewhere in New York.

Despite its 800 dams in the Hudson watershed, with about 30 of them being first barriers on Hudson tributaries that block movements in and out of the Hudson, we are not aware of a single dam removal or fish passage project having yet occurred. Some fish passage projects have been completed on Long Island and a volunteer working group meets periodically but the efforts are piecemeal. There also may be possibilities for fish passage within New York City past dams on park ponds. To move forward on stream restoration, dam removal, and fish passage in the Hudson watershed and lower New York State there needs to be an entity funded that will provide strong leadership, taking advantage of the federal and private funds available for such purposes. We propose that one or more stream restoration specialists, employed either by the state or an NGO and devoted one-hundred percent for at least several years are needed to bring the emerging paradigm of dam removal and fish passage to New York.

(2) Black Wall and Rulers Bar Marsh Restoration Community Planting Project

Significant investments have been made by government and non-profit organizations in recent years to improve the conservation and restoration of marsh island habitat in Jamaica Bay. It is estimated that 1,400 acres of tidal marsh have been lost from the system since 1924, at a rate that has been increasing in recent years. In response to these losses, the U.S. Army Corps of Engineers (USACE), the New York City Department of Environmental Protection (NYCDEP), New York State Department of Environmental Conservation (NYSDEC), National Park Service (NPS), and the Port Authority of New York and New Jersey (PANY/NJ) have focused on restoring these islands.

To date the following marsh island restoration has occurred within the Bay.

- 2006/2007 – Forty acres at Elders Point East Marsh Island was restored as mitigation to offset environmental impacts of the New York & New Jersey Harbor Deepening Project (HDP).

- 2010 - USACE, in partnership with the Port Authority of New York and New Jersey, the National Park Service, NYSDEC and NYSDEC restored approximately 40 additional acres at Elders Point West as a result of the beneficial use of dredged material from the HDP.

- 2012 – As part of the HDP, Ambrose Channel sand was beneficially used to restore approximately 44 acres or wetlands (through hummock transplanting, planting and seeding) at Yellow Bar Hassock. In addition, sand was beneficially used to restore Black Wall (~16 acres) and Rulers Bar (~8 acres) Marsh Islands funded 100% by NYSDEC and NYCDEP. Additional funding (currently $100,000 from NYCDEP) is available to establish wetland vegetation on these islands via a community-based planting effort led by

NYCDEP, EcoWatchers, Jamaica Bay Guardian and the American Littoral Society. However, if additional funds are secured, programs can be leveraged and additional acres of wetlands can be planted. The additional funds would be spent on plant materials, transportation, supplies or monitoring.

Project Description:
Spartina alterniflora will be planted throughout the low marsh zone. A mixture of Spartina alterniflora, Spartina patens (salt hay), and Distichis spicata (spike grass) will be planted in the zones between low marsh and upland. Spartina alterniflora will be planted throughout the site at a spacing of 24 inches on-center for in an elevation range from 1.5 to 2.25 ft. In the elevation zones between low marsh and upland (2.25 to 3.3 ft); a "tri-plug "mixture of Spartina alterniflora, Spartina patens, and Distichlis spicata will be planted. All planted vegetation will be fertilized with 18:6:11 Osmocote® slow release fertilizer at a rate of 15 g per plug and 30 g per quart pot. Natural recruitment and seeding would also be incorporated into the wetland design.

The restoration opportunities at Black Wall and Rulers Bar Hassock will provide first hand restoration opportunity for the local stakeholders to participate as well as an opportunity to learn about and appreciate the biodiversity of the area. NYCDEP will oversee plant installation efforts using volunteers from the community, general public, and local schools. Government staff from the above mentioned partner agencies will also help with planting.

By complementing the other ongoing efforts, this project will continue to enhance partnerships with the public, enhance environmental stewardship and educational opportunities through hands-on engagement of the local community in a large-scale restoration project.

Budget: $75,000

(3) Shoreline Resiliency and Ecological Enhancement Demonstration Project

All levels of government and the full gamut of public and private institutions are actively discussing how we can protect our waterfront from future storm events like Sandy. An important part of this discussion is the need to simultaneously achieve this needed protection and our ecological and public assess goals. This project proposes to advance new shore protection designs that meet engineering and economic requirements as well as enhance and rehabilitate our ecologically degraded shore-zone ecosystems. This idea has many supporters, including the NYC Department of Planning, the NYC Economic Development Corporation, the Corps of Engineers, and the NY State Department of Environmental Conservation.

The demonstration project aims to develop a design for a resilient and ecologically enhanced shore zone for the "Dockside" property on the northern end of the riverfront in the Village of Cold Spring, New York. The project will be a partnership with The Hudson River Foundation, the New York Department of Environmental Conservation, the Hudson River National Estuarine Research, the property owner and many other regional and local stakeholders.

Project Description
The Hudson River foundation will lead a team of scientist to develop a set of ecological principals to guide the design. The Hudson River Estuary Program will be responsible for overall project coordination, working closely with all involved stakeholders including the Village of Cold Spring, the Village of Cold Spring LWRP Special Board, Friends of Fahnestock State Park, the New York State Office of Parks, Recreation and Historic Preservation and

State and Federal regulatory staff during all phases of the project to develop the restoration pilot plan. It is the expectation that all partners will support efforts to seek additional funding for implementing the project after the completion of this design pilot project. Additional project details include:

- Funding will be used for the developing a design for a resilient and ecologically enhanced shore zone for the "Dockside" property in Cold Spring, NY.
- Project stakeholders will have multiple opportunities to review and provide input into the design process. This may include document review meetings, site visits and public meetings.
- The scope of the project and whether it includes a larger portion of the shoreline to the south of the eroding shore will be determined during the initial design phase and will depend on the amount of funding available.
- Final products will include reasonable and necessary options for stabilizing the shoreline in a manner that is consistent with the Hudson River National Estuarine Research Reserve's Sustainable Shorelines Project and existing State and Federal regulations.
- Project partners will then use the developed design to pursue funding opportunities to continue with implementation and construction.
- Once constructed, the site will serve as a 'Sustainable Shorelines Demonstration Project'. Interpretive signs will be developed and installed describing the project and crediting partners.

Budget: The estimated budget for the project is $75,000