Responding to **major storm impacts**

Ecological impacts of Hurricane Sandy on Chesapeake & Delmarva Coastal Bays

BACKGROUND: The National Fish and Wildlife Foundation established a Hurricane Sandy Wildlife Response Fund with the following objectives: 1) Conduct a rapid assessment of Hurricane Sandy impacts from North Carolina to Rhode Island, with emphasis on habitats and associated wildlife. Various organizations including government agencies, non-government organizations, and academic institutions are conducting these assessments and they will be integrated into a summary report. The goal of the summary report is to effectively communicate the integrated impacts of Hurricane Sandy to U.S. congressional leadership and the broader public. 2) Undertake limited mitigation activities to ameliorate Hurricane Sandy impacts where feasible.

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ON THE COVER: Satellite image of Hurricane Sandy ©Terra Modis; debris and damage on the beach road on Assateague Island ©NPS-ASIS; new inlet created in the Delmarva Coastal Bays following Hurricane Sandy ©USGS; Great Falls after Hurricane Sandy ©Kevin Borland; newly created overwash habitat on Assateague Island ©NPS-ASIS.

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Photo: Assateague Island National Seashore, NPS

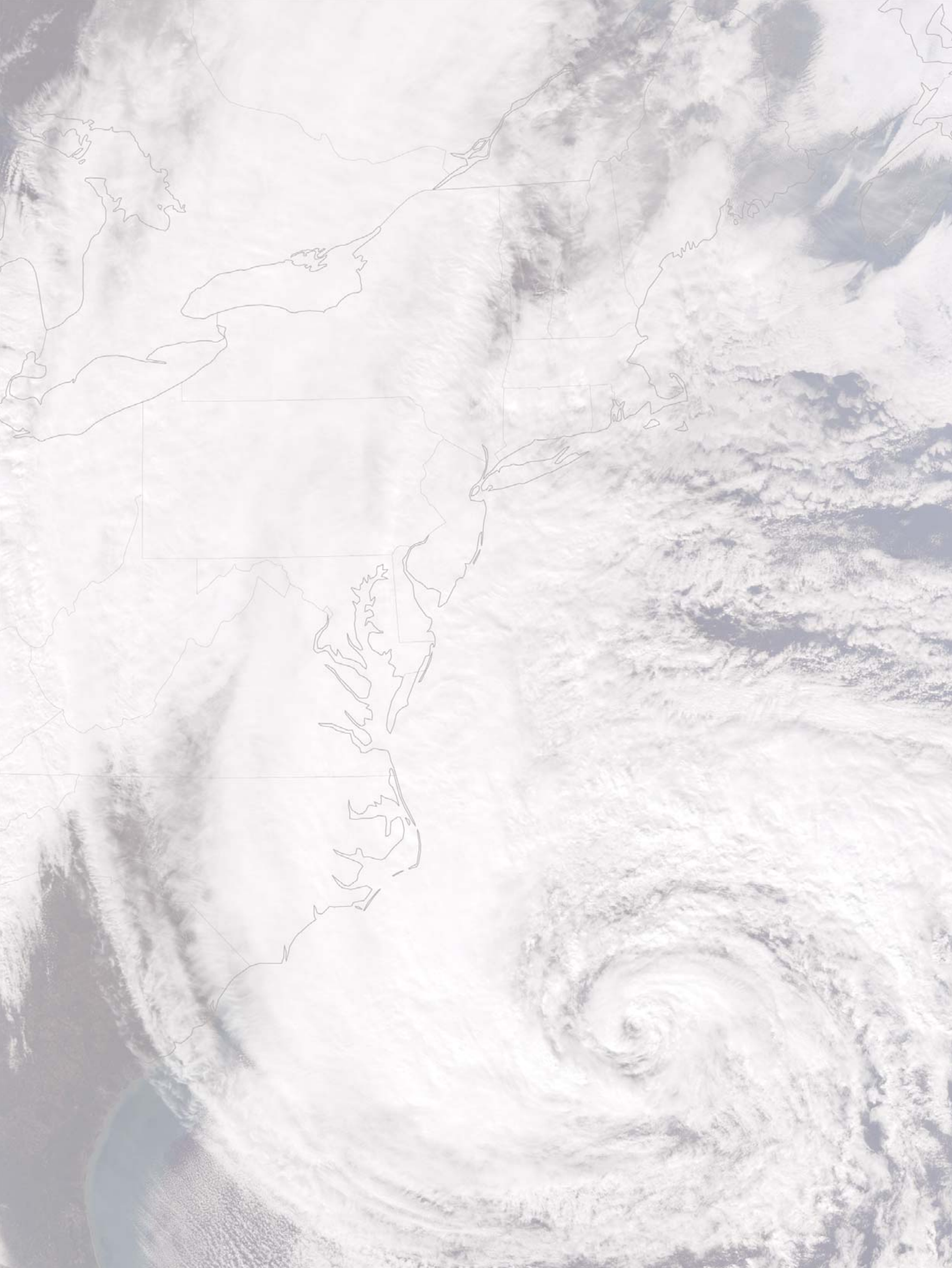


Photo: NASA Earth Observatory image by Jesse Allen

Executive Summary

Superstorm Sandy, a combination of a hurricane and nor'easter, brought about catastrophic damage in the mid-Atlantic region in October 2012, with loss of life and destruction of property and infrastructure. The ecological impacts of Sandy are being assessed and this report focuses on the rapid assessment of ecological impacts south of the storm track, in particular– Chesapeake Bay and the Delmarva Coastal Bays. The timing, magnitude, and storm track all influence the severity and type of impacts.

To better understand the impacts of Hurricane Sandy in 2012, a comparison with previous storms was made: in particular, Tropical Storm Agnes in 1972 and Tropical Storm Lee in 2011. The timing of Hurricane Sandy and the position of Chesapeake and Delmarva Coastal Bays ameliorated the impacts of the storm in this region.

A key feature in the Chesapeake watershed (64,000 mi^2) is the Susquehanna River watershed (27,500 mi^2), and the Conowingo Dam, near the Susquehanna River mouth near the head of Chesapeake Bay. The Conowingo Dam was constructed in 1928 and the reservoir behind the dam has been filling with sediment since construction. In September 2011, Tropical Storm Lee water flows resulted in significant scouring and sediment input into Chesapeake Bay but Hurricane Sandy does not seem to have caused appreciable scouring since the flows did not reach the critical threshold for scouring.

In Chesapeake Bay, the water quality impacts of Hurricane Sandy appear to have been ephemeral but habitat and fisheries impacts, particularly due to sediment mobilization and deposition, will be more lasting impacts that require attention.

In the Delmarva Coastal Bays, the impacts of Hurricane Sandy are likely to be more acute but some aspects of storm impacts may actually be positive. The beach overwash that occurred on Assasteague Island may have created more suitable habitat for some rare flora and fauna. In particular, a threatened bird species (piping plover), a threatened plant species (seabeach amaranth), and a rare insect (tiger beetle) could benefit from new overwash habitat. In contrast, key bird nesting and roosting islands, in particular Skimmer Island in Isle of Wight Bay, may have been damaged by the storm surge and sand erosion.

Photo: Patrick J. Hendrickson / Highcamera.com

Aerial image of a new inlet created on Assateague Island during Hurricane Sandy.

Position relative to storm track affects impacts

Storm track

When evaluating the impacts of tropical storms, the relative position in relation to the storm track affects the relative wind speeds, storm surge and rainfall intensity. In the Northern Hemisphere, tropical storms and hurricanes exhibit a counterclockwise circulation of winds near the earth's surface, and maximum storm surge occurs in the northeast quadrant of the wind field. Hurricane Sandy's path traveled north of Chesapeake and Delmarva Coastal Bays, eventually making landfall the evening of October 29, 2012 near Atlantic City, New Jersey; therefore, the major winds and storm surge occurred north of these bays, but significant rainfall occurred south of the storm track directly centered on Chesapeake Bay. The eye of Hurricane Sandy crossed the northern reaches of the Chesapeake Bay, and well north of the Delmarva coastal bays. Winds during the storm started from the northwest and transitioned to the southwest as the storm moved inland, sparing Maryland and Delaware's Bays of the stronger storm surges that occurred north of the storm. These westerly winds resulted in water being blown out of the western side of the Chesapeake and onto the eastern side of the Bay, resulting in wind–driven flooding on the eastern shore. In addition, a full moon occurred on October 29, resulting in higher than normal high tides. In contrast, Hurricane Isabel traveled up the western side of Chesapeake Bay in 2003 and severe winds and an appreciable storm surge resulted.

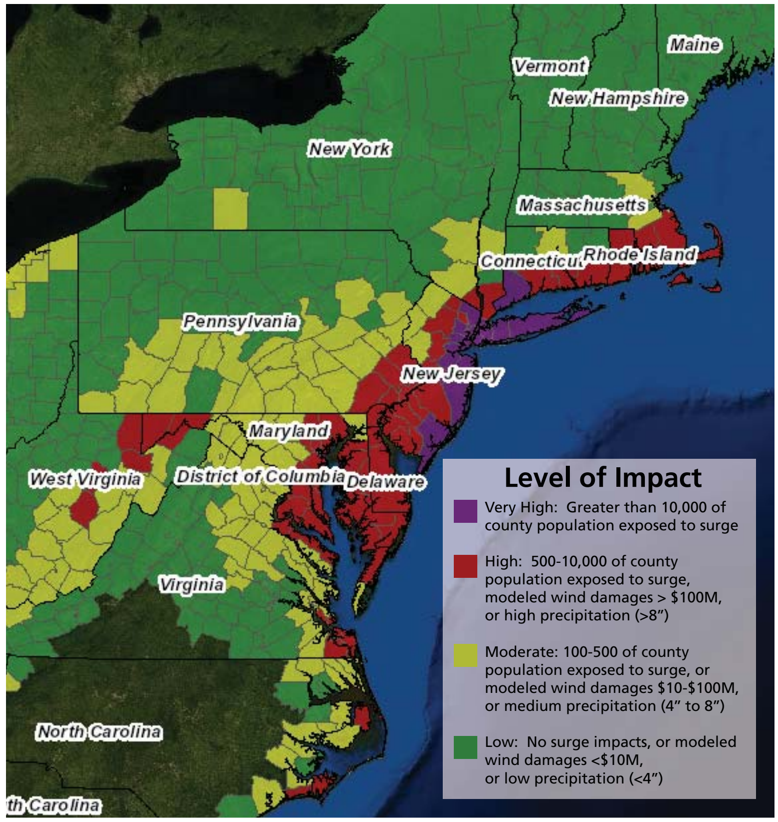
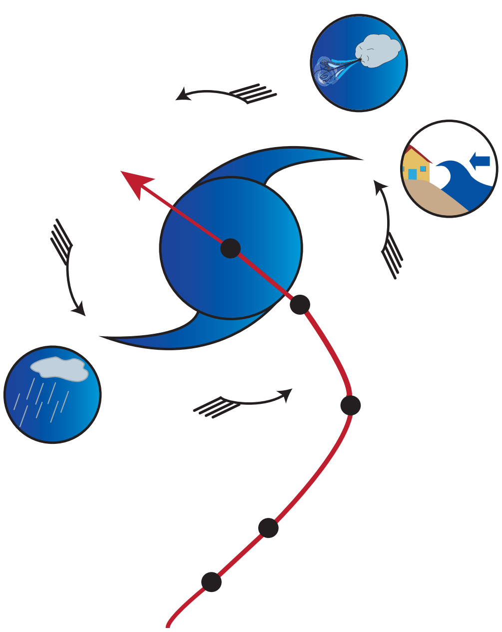


Photo: ArcGIS FEMA Online Portal, FEMA MOTF-Hurricane Sandy Impacts

FEMA Modeling Task Force (MOTF)-Hurricane Sandy Impact Analysis. A composite of surge, wind, precipitation, and snow impacts are used to predict impacts for each County. Surge impact assessments are based on worst-case scenarios using maximum of maximum (MOM) hurricane storm surge per Saffir-Simpson hurricane category, which may result in conservative estimates of impacts. (http://fema.maps.arcgis.com)



Conceptual diagram illustrating the the main threats from hurricanes and tropical storms that result in loss of life and destruction of property. In the Northern Hemisphere, hurricanes exhibit a counterclockwise circulation of winds near the earth's surface. Due to this counterclockwise pattern, maximum winds and maximum storm surge occur in the northeast quadrant of the wind field, and maximum rains occur in the southeast quadrant of the wind field.

Comparing Tropical Storm Lee to Hurricane Sandy

Sediment plumes into Chesapeake Bay

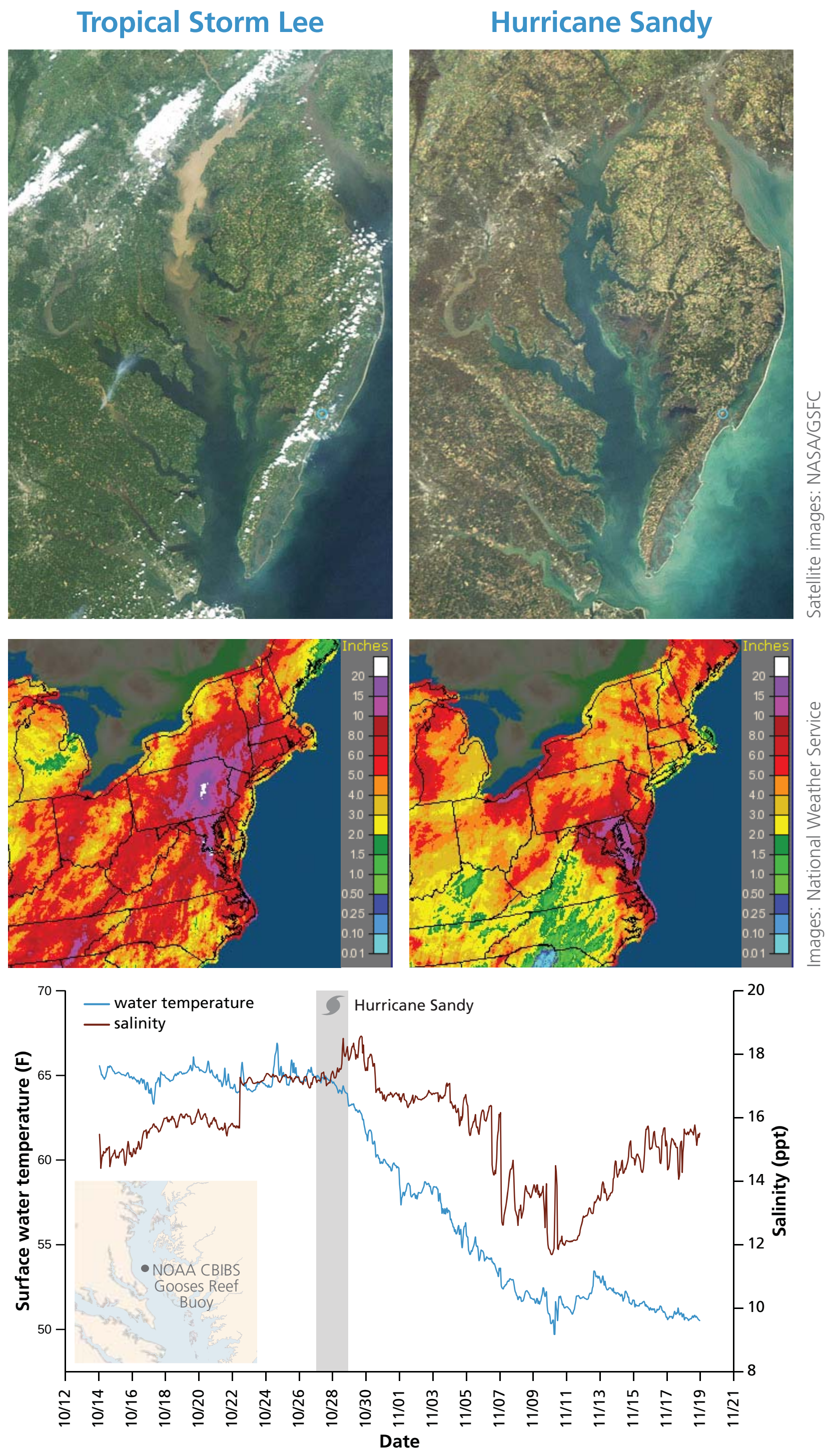
A visual comparison of the sediment plumes into Chesapeake Bay was made directly after two tropical storms: Tropical Storm Lee in September 2011 and Hurricane Sandy in November 2012. Satellite images were taken one week after both storm events, showing the longer-term impacts of Tropical Storm Lee. The extensive plume from Tropical Storm Lee was evident from the head of the Bay to the mouth of the Potomac River, approximately 100 miles downstream from the Conowingo Dam. In contrast, virtually no sediment plume was evident in the upper portion of Chesapeake Bay from Hurricane Sandy. The sediment plumes in the western shore tributaries were more or less similar in both storm events.

Precipitation patterns

The precipitation maps of both Tropical Storm Lee and Hurricane Sandy illustrate the extensive size of both storms, covering large portions of the eastern United States. The maximum precipitation amounts were similar in both storms, but the spatial patterns differed. Intense rainfall occurred in the Susquehanna River watershed during Tropical Storm Lee. During Hurricane Sandy, intense rainfall was concentrated on Chesapeake Bay and immediately adjacent portions of Maryland, with much less rainfall in the Susquehanna watershed. The differences in the precipitation patterns resulted in much higher flows of the Susquehanna River following Tropical Storm Lee.

Salinity and temperature

Comparing salinity pre- and post-Hurricane Sandy in the upper and mid–Chesapeake Bay revealed elevated salinities pre-Sandy, and depressed salinities post-Sandy. A continuous monitoring sensor in the mid-Bay region detected rising salinities through a dry summer and a dramatic drop in salinity associated with Hurricane Sandy. Chesapeake Bay experienced a major drop in surface water temperature (10 °F; 6 °C), likely due to water column mixing associated with Hurricane Sandy's winds.



Top: Comparing satellite pictures of Chesapeake Bay shortly following each storm event shows that sediment input from Conowingo Dam, as well as other tributaries, was much greater during Tropical Storm Lee (image taken 14th September 2011) than Hurricane Sandy (image taken 11th November 2012).

Middle: The rainfall patterns for both events was also significantly different, with rainfall during Tropical Storm Lee heaviest in the Susquehanna watershed of the Chesapeake Bay, while rainfall during Hurricane Sandy was heaviest in Maryland.

Bottom: Data collected at NOAA CBIBS Gooses Reef buoy shows that salinity and surface water temperatures dropped significantly following Hurricane Sandy (data from NOAA Chesapeake Bay Interpretive Buoy System).

Timing of storm events affects impacts

Positive and negative impacts

Runoff from Hurricane Sandy was laden with sediment, nutrients, contaminants, and debris. All pose a significant threat to the health of aquatic grass beds throughout the Chesapeake Bay and coastal bays. These underwater habitats provide shelter for many fish species, help improve water quality, and protect our shorelines.

The seasonal timing of key species in Chesapeake Bay and the occurrence of major storms affects the level of impact. By the time Hurricane Agnes (June 1972) reached the Mid Atlantic region, it had been downgraded to tropical storm status; however the timing of the storm was particularly devastating, as it occurred during important reproductive stages for oysters and crabs, and the early growing season for aquatic grasses. In comparison, Tropical Storm Lee occurred in late September, while Hurricane Sandy occurred in late October, leading to reduced impacts based on seasonal timing.

Oysters can benefit from storm events as freshwater input reduces disease (top), while blue crabs are highly mobile and migrate to avoid any negative impacts associated with storm events (below).

Photo: Ben Fertig, IAN Image Library

Photo: istockphoto.com

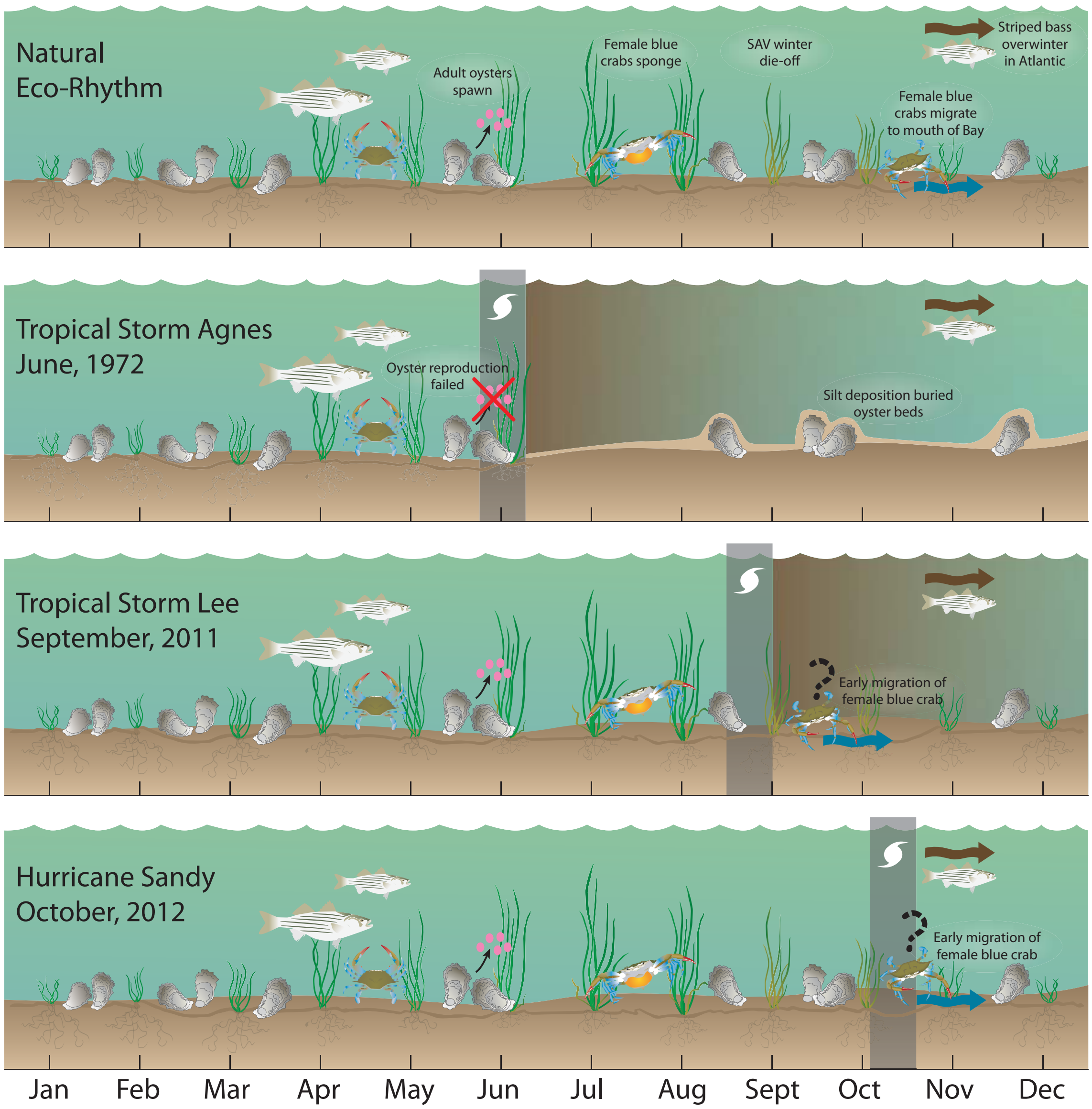
Excess nutrients and organic material introduced by storm runoff can fuel algal blooms, leading to low dissolved oxygen conditions, especially during the warmer summer months. As Hurricane Sandy occurred late in October when low dissolved oxygen is not normally an issue and algal blooms are less likely to develop, there was little impact on Chesapeake Bay dissolved oxygen levels.

There can be some positive effects of tropical storms as well as negative impacts. Oysters can benefit from reductions in salinity since the two major diseases (MSX and Dermo) are intolerant of low salinity. Infections are rare at low salinities, and significant increases to parasites usually occur during periods of reduced rainfall when higher salinity waters protrude into the northern bay. In addition, MSX and Dermo are highly influenced by temperature, and if oysters are exposed during lower temperatures (late in the season), infection can be delayed until the following summer.

Another example of positive effects of tropical storms is the mixing that occurred in Chesapeake Bay waters following the high winds during Hurricane Irene in late August 2011. That summer, waters in the Chesapeake Bay main-stem experienced one of the lowest dissolved oxygen content on record, so the high winds from the storm event completely mixed the water, improving oxygen levels.

Other species, such as blue crabs, are highly mobile and can migrate to optimal regions and avoid negative impacts associated with storm events, such as decreased water temperature or reduced salinity.

Comparing impacts of storm events



Storm events such as Tropical Storm Agnes (June 1972), Tropical Storm Lee (September 2011) and Hurricane Sandy (October 2012) can disrupt the normal eco-rhythm of species within Chesapeake Bay. For example, increased freshwater inputs can trigger early migration of female crabs to more saline waters at the mouth of the Chesapeake Bay, while increased sediments can cause widespread seagrass die-off and bury oyster beds.

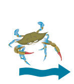
 The timing of storm events can have major impacts of the life histories of Chesapeake Bay flora and fauna.

 While the life histories of many Chesapeake Bay flora and fauna are well understood, many uncertainties remain about the impacts of major storm events. Many of the potential impacts are not observed until the next growing season.

 Oyster reefs provide habitat for many aquatic species.

 Adult oysters spawn during the summer months, typically June through August.

 Female blue crabs spawn two to nine months after mating, carrying fertilized eggs in a mass, or “sponge” on abdomen.

 After mating, female blue crabs migrate to high-salinity waters to over-winter before spawning.

 The peak growth period for aquatic grasses occurs during summer months. In the winter, plants senesce but reappear the following spring when temperatures increase.

 Striped bass are anadromous: they spend their adult life in the ocean but return to freshwater to spawn.

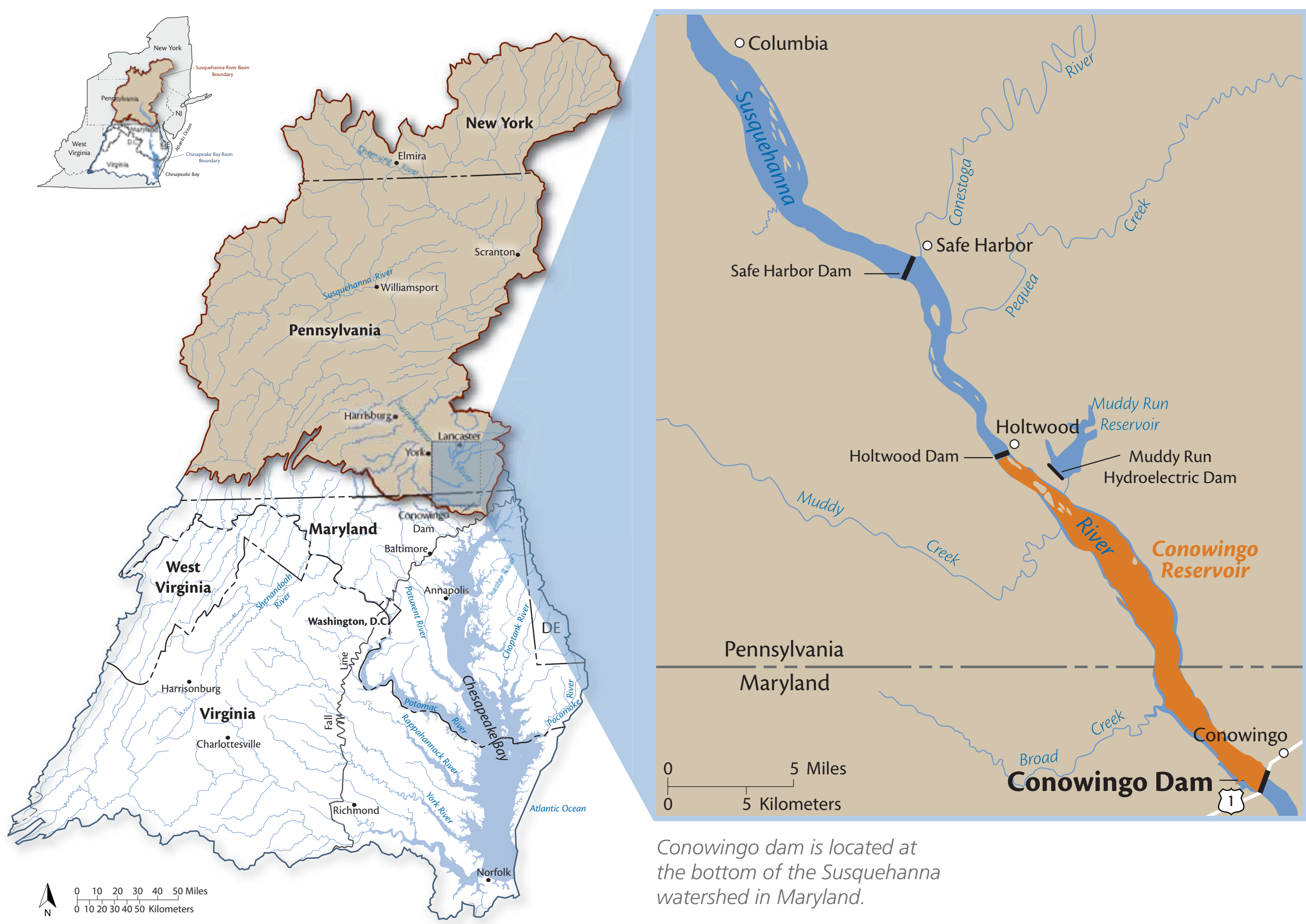
Conowingo Dam infilling and scouring

History of Conowingo Dam

The Susquehanna River watershed (27,000 mi^2) is the largest watershed within the greater Chesapeake watershed (64,000 mi^2), providing roughly 50% of freshwater flow into the Bay. The Conowingo Dam is the farthest downstream of several hydroelectric dams along the Susquehanna River. These dams are important in controlling the downstream transport of nutrients and sediments from the Susquehanna River basin into Chesapeake Bay. Construction of the dam was completed in 1928 and the reservoir has been infilling with sediments since. As the Conowingo Reservoir is approaching its sediment storage capacity, more sediment and associated nutrients are being passed into the Chesapeake Bay. During the period from 1996–2004, the scouring threshold of the dam dropped from roughly 400,000 $ft^3 s^{-1}$ to a range of 175,000–300,000 $ft^3 s^{-1}$. Scouring is now occurring at lower high flows than it has in the past. Conowingo Dam has 53 flood control gates that can be opened during high flow events to relieve pressure and maintain water levels within the reservoir.

Photo: Jane Thomas, IAN Image Library

All 53 flood control gates were opened during the largest recorded flow associated with Tropical Storm Agnes in 1972. Tropical Storm Lee resulted in 44 flood gates opened; and Hurricane Sandy had four gates opened.



Conowingo dam is located at the bottom of the Susquehanna watershed in Maryland.

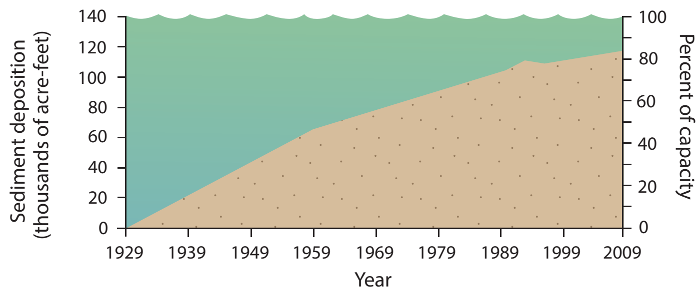
Sediment deposition

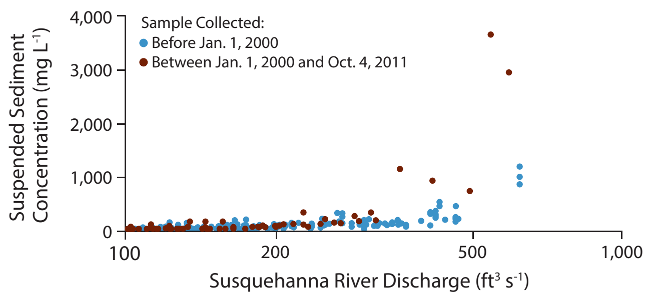
Sediment deposition in the Conowingo reservoir has accumulated over the lifespan of the dam, and the rate of accumulation has slowed as the sediment levels reach a dynamic equilibrium. The capacity of the reservoir has not been filled, but will never achieve complete infilling due to scouring. As the reservoir fills, it no longer acts as a major sink for nutrients and sediments instead, at a steady state, there is an equal balance between the nitrogen, phosphorus and sediments that enter the reservoir, and those flowing into the Chesapeake Bay.

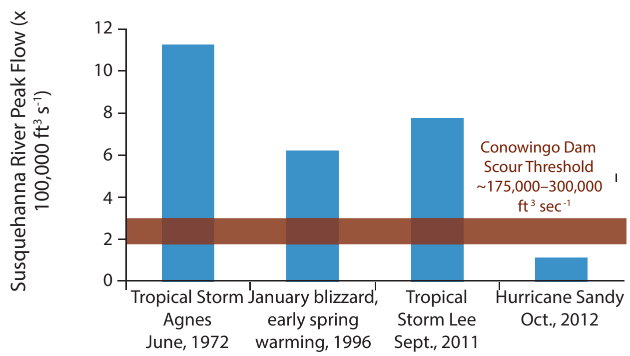
The relationships between Susquehanna River discharge levels with a) suspended sediment concentrations, b) total phosphorus, and c) total nitrogen have similar patterns. In all three relationships, low concentrations were observed at discharge levels below about 175,000 $ft^3 s^{-1}$. Furthermore, the highest concentrations were only observed in samples collected since 2000. These recent high concentrations of sediments and nutrients indicate the importance of sediment infilling of the Conowingo reservoir and sediment scouring at high flows.

A comparison of representative high flow events of the Susquehanna River puts Hurricane Sandy into a broader perspective. The highest recorded Susquehanna River flow–exceeding one million $ft^3 s^{-1}$ was recorded during Tropical Storm Agnes (June 1972), well in excess of the scouring threshold. In 1996, high winter precipitation values, and an early spring warming resulting in high flows, and Tropical Storm Lee in 2011 also exceeded the scouring threshold, but Hurricane Sandy (170,000 $ft^3 s^{-1}$) was below the scouring threshold.

The predicted and observed changes in fluxes of suspended sediments, total phosphorus, and total nitrogen over Conowingo Dam due to sediment infilling indicate that sediments and phosphorus will bypass the dam, but not nitrogen during high flow events. Sediment and associated total phosphorus loads are increasing over the past 15 years (since 1996) since not as much is being trapped within the reservoir. However, nitrogen has shown a slight decrease since it is not affected by reservoir filling. The observed doubling of suspended sediment loads and 1.5 times increase in total phosphorus represent appreciably higher loads to Chesapeake Bay due to sediment infilling, impacting the ability of the Chesapeake Bay watershed jurisdictions to meet the federally mandated Total Maximum Daily Load (TMDL) for nutrients and sediments established in December, 2012.







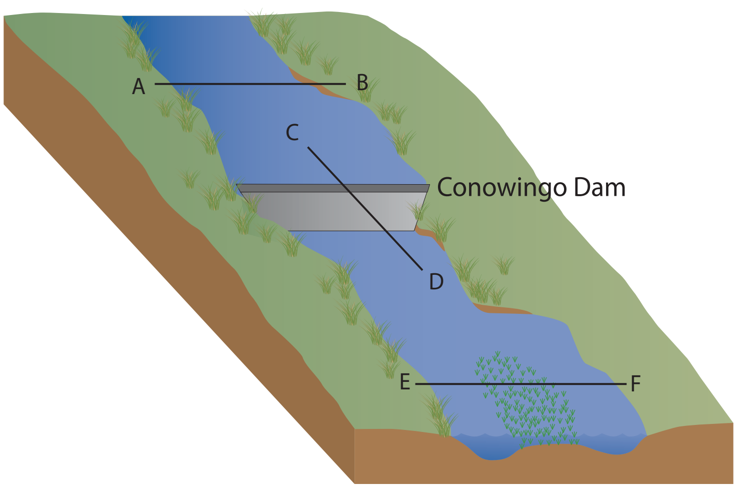
Top: Sediment deposition in the Conowingo Reservoir has increased since 1929, with a slight decrease occurring in 1996 (adapted from Hirsch 2012; data from Langland, 2009).

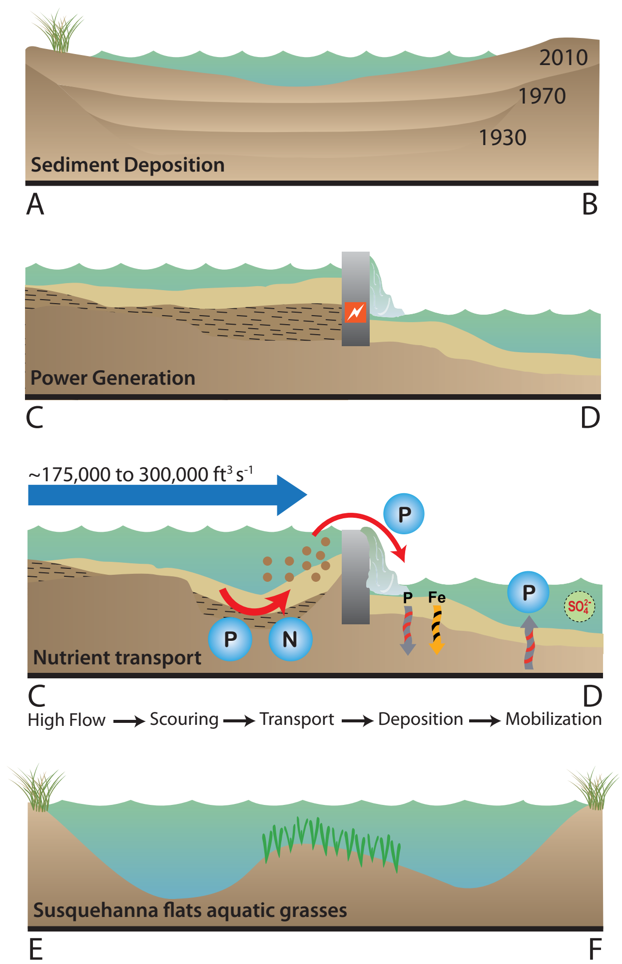
Middle: Since 2000, sediments are not effectively trapped by Conowingo Dam at high flows (adapted from Hirsch, 2012).

Bottom: Comparison of Susquehanna river flow during major storm events (data from USGS).

Key processes of Conowingo Dam

The cross-section above the dam (A-B) shows the sedimentation underneath the shallowing reservoir that has been occurring since the dam was constructed. The cross-sections through the dam (C-D) illustrate 1) the hydraulic head created by the dam which is used to generate electrical power, and 2) the scouring of sediments and transport of sediments and phosphorus over the dam during high flows (175,000 to 300,000 $ft^3 s^{-1}$). Iron binding with phosphorus in freshwater portions of Upper Chesapeake Bay is replaced by sulfate transported into the Bay with seawater, making phosphorus more bioavailable. Phosphorus is the major limiting nutrient for plant growth seasonally in the Upper Bay. The Susquehanna flats region in Upper Chesapeake Bay is depicted in the cross-section below the dam (E-F), and contains a large aquatic grass meadow which has had a large resurgence since 2002. The Upper Bay region has consistently had the best bay health index values, based on water quality (dissolved oxygen, Chlorophyll *a*, and water clarity) and biotic indices (aquatic grasses, benthic index of biotic integrity, and phytoplankton index of biotic integrity). In addition to consistent freshwater flows, lack of depth, and stratification, the large aquatic grass meadow in the Susquehanna flats has been a large contributing factor in these high bay health index values.





Conceptual depiction of Conowingo Dam reservoir and Susquehanna flats.

Cross-section A–B shows that annual sediment deposition since 1929 is making the dam shallower.

Cross-sections C–D comparisons show that high water flow ranging from 175,000 to 300,000 $ft^3 s^{-1}$ causes scouring, transport of sediments and associated nutrients, deposition of phosphorus and iron, and mobilization of phosphorus in reaction with salt water.

Cross-section E–F shows the seagrass beds that grow on Susquehanna flats.

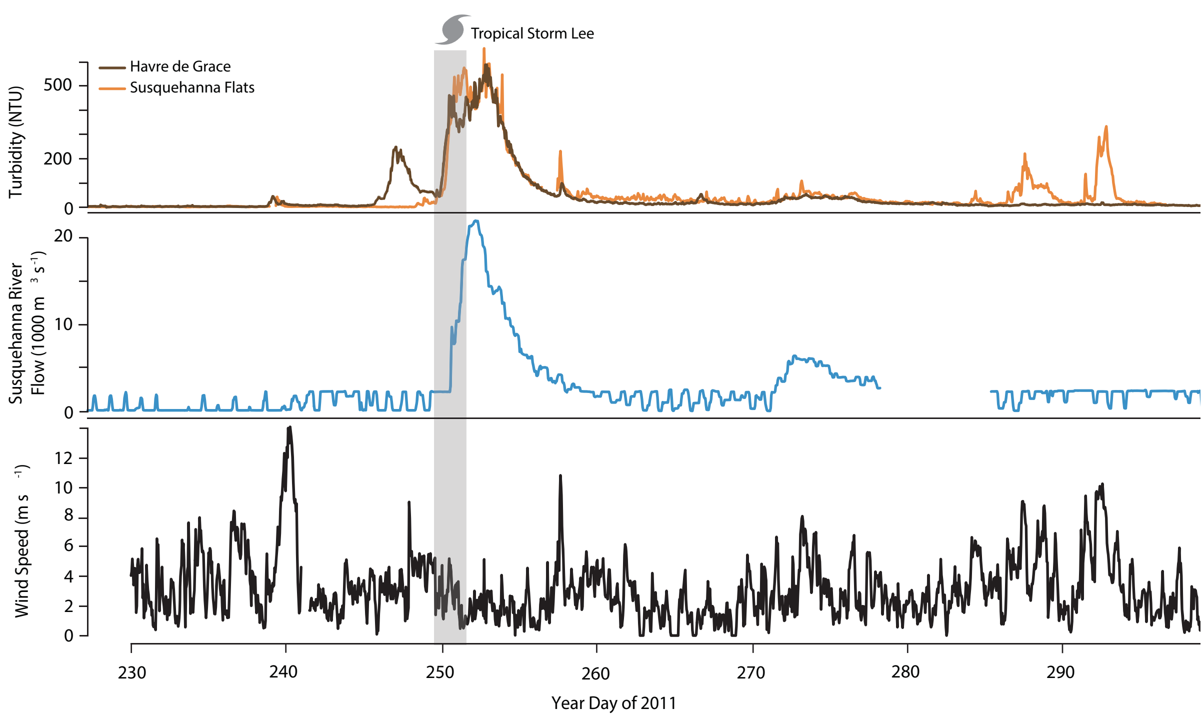
Susquehanna flats aquatic grasses:

Comparing Tropical Storm Lee to Hurricane Sandy

Continuous monitoring of turbidity adjacent to and within a dense meadow of aquatic grasses covering the Susquehanna flats just below Conowingo Dam was used to assess impacts of suspended sediments from the Susquehanna River. Hurricane Irene in late August 2011, did not bring much rain to the Susquehanna River and the high winds did not resuspend the sediments in the Upper Bay, so a turbidity increase was barely detectable. In contrast, Tropical Storm Lee delivered a large pulse of turbidity to the Upper Bay as a result of sediment scouring from behind Conowingo Dam. Following Tropical Storm Lee, levels of turbidity were elevated. Subsequent wind events in mid-October unaccompanied with high runoff levels led to high turbidity events, even though these wind events were lower than Hurricane Irene wind speeds. The high turbidity from wind resuspension only occurred at the Susquehanna flats station, and not in the adjacent Havre de Grace channel. These data support the concept that scoured fine-grained sediments from behind Conowingo Dam led to a burst of turbidity which settled out on the bottom, but has remained available for wind resuspension for much of the 2012 growing season. Thus, the impacts of a major scouring event can persist for an extended time period. During Hurricane Sandy, turbidity at Havre de Grace increased, however, it was still six times lower than turbidity observed during Tropical Storm Lee. The impact of Lee on aquatic grasses at the flats was substantial. The aquatic grasses made a strong recovery in the following 2012 growing season, although deeper portions of the meadow were reduced. Though we won't know if there were any impacts on aquatic grasses from Hurricane Sandy until the 2013 growing season, it is likely that these impacts will be minor in comparison to previous storm events, as turbidity was lower and the storm happened late in the growing season when plants had already begun to senesce.

Photo: Cassie Gurbisz, Horn Point Laboratory, UMCES

Aquatic grasses at Susquehanna flats have helped to improve water quality.



During Tropical Storm Lee, high amounts of suspended sediments entered the Chesapeake Bay and were deposited onto Susquehanna Flats. In the months following Tropical Storm Lee, wind–driven resuspension of these sediments was observed during several high wind events. The high turbidity from wind resuspension only occurred at the Susquehanna flats station, and not at the adjacent Havre de Grace channel. Turbidity data from MDDNR CONMON program (Eyes on the Bay); Susquehanna River discharge data from USGS; and wind speed data from NOAA CBIBS.

Impacts to Delmarva Coastal Bays

The Delmarva Coastal Bays include the barrier island lagoons of Little Assawoman Bay, Assawoman Bay, Isle of Wight Bay, St. Martin River, Sinepuxent Bay, and Chincoteague Bay. The embayments and their watersheds include parts of southern Delaware, all of coastal Maryland, and parts of Virginia.

These shallow lagoons are formed by two elongated barrier islands: Fenwick Island and Assateague Island. There are two inlets that connect the Delmarva Coastal Bays with the Atlantic Ocean: Ocean City inlet to the north and Chincoteague Inlet to the south. Fenwick Island to the north of Ocean City inlet is heavily developed and an ongoing beach nourishment program in which offshore sand is pumped inshore maintains the island position in virtually the same location as it was when the Ocean City inlet was formed in 1933. The inlet is stabilized by a series of groins as well.

South of Ocean City inlet, Assateague Island is managed as a contiguous protected area by the Assateague Island National Seashore (National Park Service), Assateague State Park (Maryland Department of Natural Resources), and Chincoteague National Wildlife Refuge (US Fish & Wildlife Service). Assateague Island does not have a beach nourishment program, although a sand bypass program facilitates the southern longshore drift of sand around Ocean City inlet. As a result of sea level rise, Assateague Island has migrated inshore since 1933, as the natural processes of overwash, deposition, and erosion take place. Thus, Assateague Island is now substantially further west than Fenwick Island.

The watersheds of the Delmarva Coastal Bays are relatively small, with little elevation. The small watersheds mean that these bays can be strongly influenced by relatively small but intense runoff events.

Location of the Delmarva Coastal Bays of Delaware, Maryland, and Virginia..

In 2012, several intense localized rainstorms resulted in localized flooding and runoff into the Delmarva Coastal Bays.

The coastal storm surge associated with Hurricane Sandy was not as substantial as experienced in New Jersey and New York, yet there was a four–foot seawater elevation observed in the Delmarva Coastal Bays. Assateague Island experienced morphological changes including overwash and beach face steepening.

Assateague Island supports several rare species, including the threatened piping plover (*Charadrius melodus*), the threatened dune annual plant species seabeach amaranth (*Amaranthus pumilus*), and two species of the rare tiger beetle (*Cicindella spp.*). The overwash is likely to have created new suitable piping plover habitat, including areas that are currently utilized for beach recreation. Protecting piping plover habitat area along the Assateague Island National Seashore has been a major focus of the National Park Service and Fish and Wildlife Service, as human disturbance can cause birds to abandon nesting sites. This may present a management challenge next summer due to potential conflicts between recreation activities and beach nesting by plovers. These bird, plant, and insect species are dependent on natural beach processes and are likely to benefit from the sand overwash caused by Hurricane Sandy.

There was a breach near the southern end of Assateague Island that occurred when elevated sea levels behind the barrier island flowed seaward into the Atlantic Ocean. This shallow breach has occurred historically and natural processes are expected to fill in over time and close the breach.

Photo: istockphoto.com

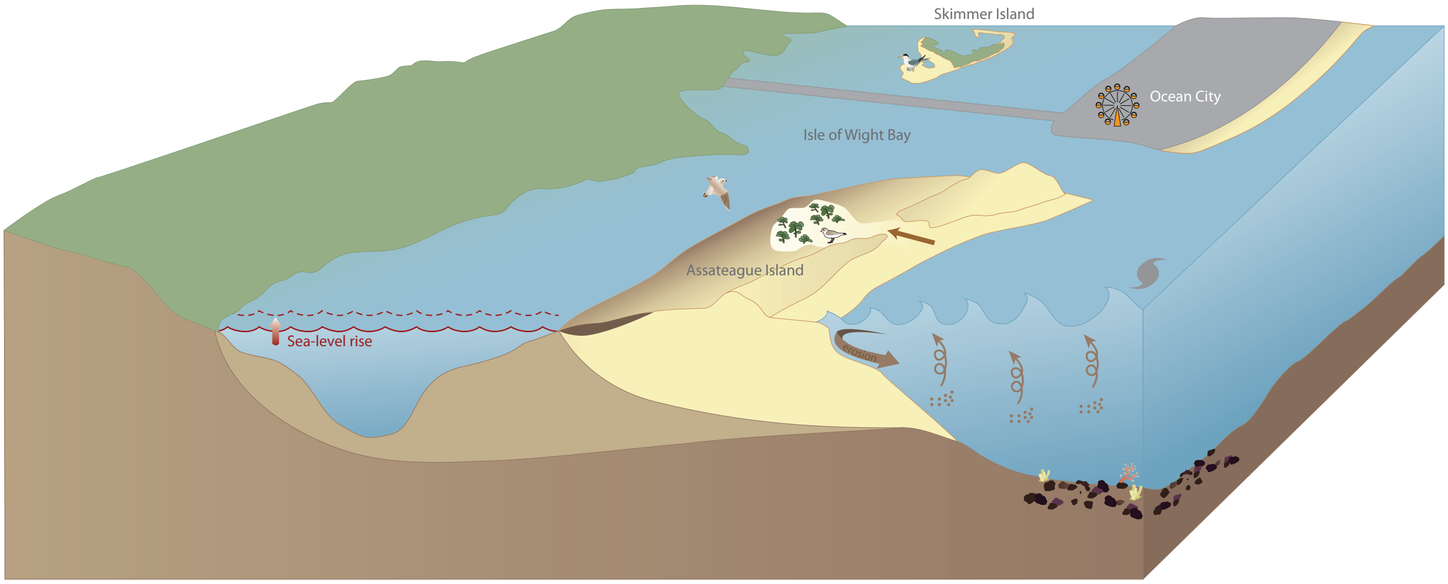
Photo: Alexandra Fries, IAN Image Library

Photo: Marshal Hedin

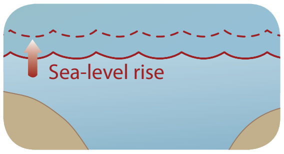
Assateague Island supports several rare species, including the Piping plover (top), seabeach amaranth (center), and two species of the rare tiger beetle (bottom). Each of these species thrives in overwash habitat created by storms.

Key physical processes occurring within the coastal bays

The Delmarva Coastal Bays are extremely vulnerable to severe storm events, and as sea level continues to rise, heightened storm waves will intensify the impacts of coastal flood waters and storm surge. This increase in storm-wave height will also affect shore erosion, and increase overwash, where sand is transported to the interior of the islands, replenishing back-barrier marshes and creating important habitat. Sediment resuspension due to storm surge can also impact benthic communities.

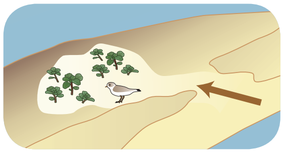


Sea level rise



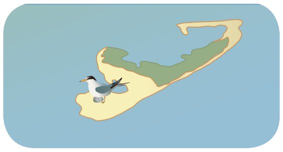
The four feet of storm surge produced by Hurricane Sandy demonstrated the extreme vulnerability of the Delmarva Coastal Bays. Over time, sea-level rise will result in increased storm wave height, enabling waves to extend further inland. Heightened storm waves will intensify the impact of coastal flood waters and storm surge, and exacerbate the processes that drive shore erosion. Monthly sea level data collected over the last 100 years at Baltimore shows a rise in sea level of about 30 cm, or 1 ft (Data courtesy of PSMSL).

Beach overwash



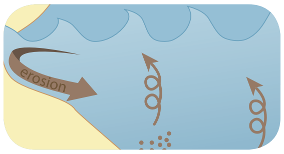
Overwash processes are important in biological and geomorphological functions of barrier islands. Overwash plays an important role in the response of barrier islands to storm events and sea level rise by transporting sand from the beach to island interiors, replenishing back-barrier marshes, and creating overwash fans. These overwash fans provide important new habitat for rare flora and fauna.

Skimmer Island



Small sandy islands in the Delmarva Coastal Bays provide seabirds with important roosting and nesting habitat safe from predators. Due to shoreline changes and sea level rise, there are very few of these small sandy islands that remain in the Delmarva Coastal Bays. A key remaining island, locally known as Skimmer Island, is located just north of the Ocean City inlet and the U.S. Route 50 bridge in Isle of Wight Bay. Several restoration projects have focused on resupplying the island with sand and fortifying its eroded shorelines with dredge material. Skimmer Island may have been negatively impacted by Hurricane Sandy, and without existing sand replenishment projects may have sustained further damage.

Sediment resuspension



Resuspension of sediments along coastal areas due to winds and storm surge can impact important benthic communities along the shoreline. Large amounts of suspended matter was observed along the Delmarva Coastal Bays and offshore in the days following Hurricane Sandy.

Conclusions & Recommendations: Chesapeake Bay

1

Conclusion: **The storm track and timing of Hurricane Sandy in October 2012 ameliorated its impacts on Chesapeake Bay. Hurricane Sandy, unlike Tropical Storm Lee in November 2011, did not result in flows that would cause major scouring of Conowingo reservoir. In addition, a prior drought reduced the impact of lowered salinities created by freshwater runoff associated with Hurricane Sandy.**

Recommendation: While Chesapeake Bay was spared the devastating impacts of Hurricane Sandy due to its storm track and timing, it is not prudent to become complacent about the potential impacts of future large storm events. There are a variety of ecosystem restoration and protection initiatives, monitoring activities, and research priorities that should be reevaluated with regards to potential large storm events with different storm tracks and timings that may result in runoff and dam reservoir scouring at more sensitive times of the growing season, leading to major impacts on Chesapeake Bay.

Specific Recommendation: Chesapeake Bay Program should conduct an assessment on the robustness of ecosystem restoration and protection initiatives to large storm events. In addition, an evaluation of the monitoring framework for event sampling and research priorities for understanding dynamics of large events is warranted.

2

Conclusion: **The Conowingo Dam reservoir has been losing capacity for sediment trapping since it was constructed in 1928; sediments and phosphorus now largely bypass the dam during high flow events. Scouring will occur more frequently during high flow caused by storm events.**

Recommendation: Investigate sediment bypass or dredging options to increase Conowingo Dam capacity for sediment trapping.

Specific recommendation: The Lower Susquehanna River Watershed Assessment is an ongoing multi agency study, led by the Army Corps of Engineers targeting sediment trapping and scouring. Develop effective ongoing communication of the findings from this assessment to Chesapeake Bay resource managers and scientists, using the Science & Technical Analysis & Reporting (STAR) group at the Chesapeake Bay Program.

3

Conclusion: **Extreme events like Hurricane Sandy are likely to increase based on regional climate predictions. Sea level rise and increased sea surface temperatures have been documented in Chesapeake Bay, and droughts punctuated by large rainfall events are likely scenarios for future climate in this region.**

Recommendation: Climate variability needs to be factored into future scenarios regarding Chesapeake Bay restoration. Research and monitoring priorities should be directed to support better ecological predictive capacity. Effective communication of the dimensions of climate change and variability needs to occur as well.

Specific recommendation: Expand the event response assessment in Recommendation #1 to include a readiness for climate change assessment. In addition, develop a climate change and extreme events response communication strategy in the Chesapeake Bay Program which includes an evaluation of the public and stakeholder perceptions of climate change and extreme events.

Conclusions & Recommendations: Delmarva Coastal Bays

1

Conclusion: Large waves from the Atlantic Ocean (up to 20-40 foot wave heights recorded off Ocean City, MD) affected the nearshore benthic habitats on the seaward side of the barrier islands. Resuspension and deposition likely affected sand flats, mud deposits, gravel beds, and soft coral/sponge communities. Offshore water quality can affect Delmarva Coastal Bays water quality.

Recommendation: Enhance coastal observing networks and both offshore and coastal bays monitoring to assess impacts of offshore water quality on coastal bays.

Specific Recommendation: The States of Maryland, Delaware, and Virginia need to partner with the federal government to survey and create baseline habitat maps for offshore habitats that are beyond the administrative boundaries of the National Park Service and US Fish & Wildlife Service (who manage Assateague Island to 0.5 miles offshore) and the Maryland Coastal Bays Program (up to the inlets). Those habitats within the 0.5 mile boundary that have been surveyed by the National Park Service need to be resurveyed.

2

Conclusion: Sandy islands of the Delmarva Coastal Bays, in particular Skimmer Island, and Dog Island Shoals in Isle of Wight Bay, may have lost increasingly rare habitats due to storm surge and erosion. Sand deposition in channels and harbors will require additional dredging.

Recommendation: Develop a strategic sand dredging plan for the Delmarva Coastal Bays so sand nourishing of critical sand island habitats can occur.

Specific Recommendations: A sand dredging strategic plan is being developed by the Army Corps of Engineers and Maryland Coastal Bays Program; Hurricane Sandy provides an impetus to accelerate this planning effort.

3

Conclusion: Beach overwash on Assateague Island created new potential habitat for key threatened and rare species of birds (piping plovers), plants (seabeach amaranth), and insects (tiger beetles). Potential habitat losses are also possible due to overwash into salt marshes and seagrass meadows in the Delmarva Coastal Bays.

Recommendation: Monitor the establishment of threatened and rare species in newly created overwash habitats. Manage and protect these habitats by changing zoning of recreational uses, and educate visitors about the importance of these newly created habitats for rare and threatened fauna/flora. Monitor the impact of overwash on seagrass beds and marshes in the following growing season.

Specific recommendation: Coordinate monitoring efforts by federal and state agencies, academic and research institutions, and non-government organizations to provide an integrated assessment of Hurricane Sandy impacts using the Science & Technical Advisory Committee of the Maryland Coastal Bays Program.

Estimated costs of short- and long-term remediation

Resource	Issues	Habitat Impacted	Species Impacted	Remediation	Partners	Estimated Costs	Name/ Agency
Deal Island Wildlife Management Area (WMA)	Erosion and leaks to dike	Tidal marsh	TBD	Replanting	MD DNR	$45,000	MD DNR
Chesapeake Bay-Crisfield Area	Submerged Aquatic Vegetation (SAV)	Eelgrass-damage won't be known until 2013 survey	Damage from local scouring	Replanting	MD DNR	TBD	Lee Karrh, MD DNR
Skimmer Island, Isle of Wight Bay	Island lost all sand used to restore it in 2010 and 2011. It lost a foot of elevation	Colonial nesting bird island	Royal terns, black skimmers	Sand replenishment of island	MD DNR, MCBP, Private marina owners	$144,000	Dave Brinker, MD DNR
Coastal Bays	Island loss	Colonial nesting bird islands	Royal terns, black skimmers, common terns, least terns	Restoration of lost and degraded islands and a comprehensive dredging plan and needs assessment to implement it	MD DNR, MCPB, Private marina owners	$550,000	Dr. Roman Jesien, MCBP
Coastal Bays	Submerged aquatic vegetation (SAV)	Eelgrass-damage won't be known until 2013 survey	Damage from overwash	Replanting	MD DNR	TBD	Lee Karrh, MD DNR
Assateague State Park	Dune repair	Dune	TBD	Repair dunes	MD DNR	$80,000	MD DNR
Ocean City, MD	Dune crossover repairs, fencing, plantings, debris removal	Dune	TBD	Repair dunes, remove debris, and re-establish plantings	MD DNR, MCBP	$1,000,000	

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