Working Briefs

A Summary of Climate Change Impacts and Preparedness Opportunities for Six New Jersey Sectors

The New Jersey Climate Adaptation Alliance is a network of policymakers, public and private sector practitioners, academics, and NGO and business leaders designed to build climate change preparedness capacity in New Jersey. The Alliance is facilitated by Rutgers University which provides science and technical support, facilitates the Alliance's operations and advances its recommendations.

Beginning in 2013, the Alliance will be undertaking a deliberative process to develop recommendations for state and local public policy that will be designed to enhance climate change preparedness and resilience in six sectors in New Jersey:

- Agriculture
- Built Infrastructure
  - o Utilities (energy and telecommunications)
  - o Transportation
- Coastal Communities
- Natural Resources
- Public Health
- Water Resources

This series of "Working Briefs" was under development when the region was affected by Hurricane Sandy. The extent of the storm's damage and the toll it has taken is unprecedented, devastating and very, very personal to so many individuals and families. The extent of destruction to personal lives, local businesses and infrastructure has changed the face of New Jersey forever. The New Jersey Climate Adaptation Alliance offers its most sincere concerns for residents who suffered as a result of the storm's impacts as well as for the many individuals who were on the front line dealing with emergencies following Sandy. The Alliance commits to work in partnerships with individuals, leaders and organizations affected by Sandy to incorporate lessons learned from their collective experience to build more resilient communities and to help enhance New Jersey's preparedness for future storm events and changes in the region's climate.

New Jersey Climate Adaptation Alliance

The mission of the New Jersey Climate Adaptation Alliance is to work through partnerships with existing public and private practitioners and leaders to identify, demonstrate, recommend and communicate policies and cost effective activities that can prepare New Jersey to better meet the anticipated impacts of climate change through the following:

1. Development of recommendations for state and local policy;
2. Enhancement of preparedness capacity, including development of tools and training where needed;
3. Facilitation of demonstration, pilot and other projects to show the value of climate change preparedness;
4. Creation of a clearinghouse of climate preparedness information and ongoing efforts in New Jersey;
5. Communications and education to the general public, decision-makers, practitioners and stakeholders;
6. Identification of science and research needs to support actions at the state and local levels.

For more information or to sign up for the New Jersey Climate Adaptation Alliance mailing list, go to: *http://climatechange.rutgers.edu/njadapt*.

A Summary of Climate Change Impacts and Preparedness Opportunities Affecting Natural Resources in New Jersey

This paper includes an analysis of impacts and adaptation strategies directly related to natural resources, defined here as ecosystems, flora and fauna. The analysis will not include the effects of climate change on water resources in terms of potable water supply or quality, or commercial aspects of natural resource such as fisheries. These topics will be covered in the agriculture and water resources scoping papers. Any current New Jersey efforts as well as current and planned adaptation practices and strategies in other states are presented as the basis for a series of recommendations to address additional needs as a starting point for discussion and prioritization of comprehensive adaptation planning for New Jersey.

Natural Resources in New Jersey

New Jersey, though it is the fifth smallest state in area and the most densely populated in the nation, has an incredible variety of landscape forms, forest and water resources, and plant and animal species. Forests of mostly oak/hickory dominate in the northern half of the state, the upland and piedmont physiographic provinces. The pine barrens of the south central part of the state are dominated by loblolly/shortleaf pine forests. The southern half of the state has 127 miles of Atlantic coastline and also a large coastal plain province.

New Jersey has five major watershed regions which are split into 20 watershed management areas by the New Jersey Department of Environmental Protection's (NJDEP) watershed management program. Wetland acres total over 636,000 in New Jersey, with almost a third of these in coastal (freshwater tidal and saline) marshes.[1] In the two hundred years between the 1780's and 1980's, almost 40 percent of the state's wetlands were lost, due mostly to development.[2] In addition to loss of acreage, this human activity has greatly affected coastal ecosystems and caused levels of many pollutants to increase.

The state's varied landscapes support abundant and diverse plant and animal species. New Jersey's location along the middle of the Atlantic seaboard means that it lies at the southern edge of the range of many northern species and the northern edge of the range of many southern species. There are more than 400 species of vertebrate wildlife, 134 freshwater fish and 336 marine finfish in the state. Coastal ecosystems in NJ have 24 endangered and threatened wildlife species, and coastal wetlands are an important stopover point for about 1.5 million migratory birds and have world's largest population of horseshoe crabs.[3]

Outside of state, local and federal parks, forests and wildlife preserves that are directly managed by government agencies, most of the state's natural resources are found on private lands. Importantly, there are more than 90 non-governmental organizations like the New Jersey Conservation Foundation, The Nature Conservancy, New Jersey Audubon and dozens of local or regional open space, watershed, trust and conservancy groups that have directly acquired or partnered to manage critical natural areas.[4] Many of these conservation organizations are conducting the cutting edge stewardship and restoration important to enhancing the resilience of the state's natural resources. .The NJDEP is the primary state agency responsible for management and programs related to protection and conservation of natural resources. The Division of Fish and Wildlife (DFW) is responsible for all wildlife in New Jersey, including the goals of protecting and managing habitats and wildlife populations and maintaining wildlife diversity. One management approach is to set aside more than 330,000 acres in Wildlife Management Areas across the state that preserve a diversity of fish and wildlife habitats from Delaware Bay coastal marshes at the southern tip of the state to the Kittatinny Ridge mountains in the northwest corner. The state's Wildlife

[1] NJDEP (2002)
[2] Dahl (1990)
[3] Cooper et al (2005)
[4] NJCF (2010)

Action Plan, developed in 2005 with input from many stakeholders, is a blueprint for conservation of species of greatest vulnerability.

NJDEP's Division of Parks and Forestry is accountable for the stewardship of 326,000 acres of state forest land. Programs relevant to climate change adaption include the Private Lands Management Program that fosters wise stewardship and management on the more than 1.5 million acres of forest lands owned by private landowners and the retention of these lands in contiguous and productive forests. Also, the New Jersey Natural Heritage Program identifies the state's most significant natural areas through a comprehensive inventory of rare plant and animal species and representative ecological communities.

The state's Coastal Zone Management Program defines Special Areas of environmental interest that are to be considered for permit approval of development projects. Also, through the Flood Hazard Area Control Act, the state encourages vegetation adjacent to surface waters to maintain bank stability and maintain filtration functions to protect water quality, which also serves to conserve important riparian habitats.

Potential Sector Impacts

Climate has a strong influence on the processes that control growth and development in ecosystems. Changes in temperature, precipitation and sea level will transform habitats, alter timing of life cycles, shift geographic ranges and spread pests, disease and invasive species to new areas. Ecosystems have adapted throughout time to changing conditions, but the current pace of climate change is outpacing past changes and will require the ability to adapt more abruptly and on a larger scale than in the past.[5] However, climate change will have varying degrees of impacts on different ecosystems and on different features or species within those ecosystems.[6] Species most affected will be those that are highly specialized or dependent on particular conditions or habitat features with narrow tolerances. It is important to note that human-induced climate change is not the only factor, nor always the most important one, initiating these impacts. Climate change will extend or exacerbate impacts or further impair ecosystems already stressed by one or more human-induced factors like development, pollution, invasive species and habitat fragmentation.[7]

Aquatic and Wetland Ecosystems

Impacts to the Resource:

Aquatic ecosystems are vulnerable to climate change. Predicted changes in timing, frequency, and duration of precipitation events, more intense storms, a shift from winter snow to rain, more frequent and longer summer droughts, and increases in temperature trends and extreme high temperatures will affect both lotic (flowing water) and lentic (still water) habitats. In terms of the impacts of climate change, aquatic environments can be divided into inland or upland freshwater systems, and coastal marshes, bays and ocean. Inland aquatic resources will be most affected by temperature and precipitation and their related impacts, while coastal and tidal areas will also be affected by storm surge, rising seas and salinity changes.

First, in non-coastal areas, changes in precipitation and temperature will have varied effects on freshwater ecosystems. Urbanization has already led to higher stream temperatures over the past hundred years, affecting fish habitat, and climate change will likely exacerbate this existing problem. Increased ambient temperatures also translate to increased evaporation, reducing flows and concentrating pollutants during periods of low stream flow, degrading water quality and habitats.[8] Drought will also lead to decreased summer streamflows.

Warmer, drier summer conditions will lead to deeper and stronger thermal stratification in lakes which will decrease the volume of the deeper, cooler, well oxygenated water that is critical summer habitat to a number of species. Increased mobilization of non-point

[5] U.S. Environmental Protection Agency (2012a)
[6] Shaffer, Griffis and Barnhart (2012)
[7] USGCRP (2009)
[8] MCCC (2010)

source nutrients, and suspended solids from more intense winter rain storms, followed by higher summer temperatures, will result in more algal blooms and growth of aquatic vegetation leading to eutrophication in lakes and impounded rivers. Higher average winter temperatures will reduce ice cover on lakes and ponds and will result in more winter sunlight and more abundant aquatic vegetation, and the shift to winter rains instead of snow will potentially lead to more runoff, flooding, greater storm damage, scour, and erosion during a time when there is reduced vegetative cover and low evapotranspiration. Flooding, and an accompanying loss of vegetative cover, could reduce many ecological functions, causing effects such as reduced primary productivity and loss of carbon storage; degradation of wildlife and in-stream aquatic habitat and water quality; and increased incidence of water-borne disease, sedimentation, pollutant loading of waterways, and surface runoff.[9]

Climate change may affect stream flow by increased flooding incidences from extreme precipitation events, and low flow occurrences in late fall. Higher summer temperatures, less summer precipitation, and an increase in drought frequency and duration will affect both water quantity and quality. Some intermittent streams may cease flowing earlier in the season and more frequently and some perennial streams may become intermittent. In some rivers and streams, coldwater habitat will be replaced by warm water habitat. This will likely be accompanied by marked changes in the species that live in these habitats. Flows can become discontinuous, creating barriers to fish movement.

Second, in coastal areas, impacts will occur in estuaries, marsh areas and also in the ocean and bays. Coastal ecosystems will be particularly vulnerable to the impact of climate change due to the nature of their locations. In addition to responding to increased temperature, variable precipitation, and extreme weather events, sea level rise will expose these critical habitats to increased loss and decimation. It is anticipated that important coastal habitats will be lost and reduction of sediment load to beaches and other coastal habitats will limit the ability of these areas to maintain accretion at a rate that could match sea level rise.

Sea level rise is a major threat to tidal wetlands. In terms of salinity, it is uncertain exactly how precipitation and sea level rise changes will affect salinity, but if changes are of a more major nature or last longer, species may not be able to adapt. Plants with limited salinity tolerance in tidal freshwater marshes are particularly vulnerable to saline intrusion.[10] If a marsh is not well-flushed, effects to species will occur.[11]

Tidal wetlands are essential spawning, nesting and foraging habitat for many animal species. Salt marshes and the adjacent tidal flats comprise one of the most productive ecosystems on earth, providing the basis of complex food chains in both estuarine and marine environments and habitat for various species of wildlife, including migrating and overwintering waterfowl and shorebirds, and the young of many species of marine organisms. For freshwater wetlands, increased salinity is a great threat may be increased salinity, and freshwater wetlands are unlikely to be able to migrate inland, as much of the more upland areas are developed.[12] Coastal wetlands, intertidal areas, and other near-shore ecosystems are subject to a variety of environmental stresses. Sea-level rise, increased coastal storm intensity, and rising temperatures contribute to increased vulnerability of coastal wetland ecosystems. It has been estimated that 3 feet of sea-level rise (within the range of projections for this century) would inundate 65 percent of the coastal marshlands and swamps in the contiguous United States.[13]

Potential impacts to the ocean are varied. Increased ocean temps will reduce oxygen, and atmospheric CO_2 will reduce ocean pH and threaten health of the ecosystem, including already stressed corals and rippling through the food chain.[14] Circulation patterns will change, with less mixing of cold and warm water in tropical and subtropical areas, affecting the ability of near-surface species to reach nutrients at lower depths.

9 Ramsar (2002)
10 MCCC (2010)
11 Kreeger et al. (2010)
12 Kreeger et al. (2010)
13 Park et al. (1989)
14 NAS (2010)

At more northern latitudes, though, mixing could actually increase with melting of sea ice, but general ocean warming will alter migration and breeding patterns and push species further northward.[15,16]

Impacts to Species

Climate change can affect the abundance, distribution and migration of various aquatic species, and the composition of species within an ecosystem. Fisheries in small rivers and lakes are believed to be more susceptible to changes in temperature and precipitation than those in larger rivers and lakes.[17] As coldwater habitats warm, coldwater species, already stressed by reduced habitats and population losses, will be especially affected. Warmer water temperatures, reduced ice cover to protect sensitive breeding patterns, and altered streamflow can all affect coldwater native fish species in northern rivers and lakes like brook trout, lake trout and whitefish. These species may be pushed upstream into smaller, cooler tributaries.

Flooding can scour stream bottoms where fish eggs are lodged. The earlier seasonal growth of plants could result in lower stream base flows earlier in the spring and negatively affect primary productivity. An earlier snowmelt that can disturb normal life cycles of aquatic insect and fish life due to increased vegetation.

Increased frequency of extreme precipitation will cause problems such as stream bank erosion and increased sediment volume, harming aquatic organisms and ecosystems. In rivers and streams, changes in water temperature will cause heat stress, increased numbers of parasites or changes in food availability, particularly affecting coldwater species,that may need to move to high-elevation streams.[18]

Non-native species will likely become a bigger problem for lake and stream ecosystems under warmer conditions.[19] Climate change can influence the establishment and spread of invasive species and can reduce resilience of native habitats to these species.[20]

Estuaries often have associated salt marsh habitat and are rich in nutrients, providing a valuable nursery for finfish, shellfish, and other macro- and micro-invertebrates, and supporting a wide range of vertebrate wildlife. These habitats are vital links in the life histories of diadromous fishes (those that spend part of their lifecycle in salt water and part in fresh water), which rely on these complex ecosystems to provide food and protection.[21] Degraded inland and coastal wetlands are likely to lead to declines in some bird species such as the American bittern, common loon and sora.[22]

In the ocean, projections based on temperature increases alone suggest that within the next several decades, 60 percent of the world's corals are likely to be severely damaged or destroyed.[23] Rising levels of carbon dioxide dissolved in the ocean can have a negative effect on marine life, as rising acidity reduces the availability of minerals that corals, some types of plankton, and other creatures rely on to produce their hard skeletons and shells. This can lead to broader changes in the overall structure of ocean and coastal ecosystems, and can ultimately affect fish populations.

Terrestrial Ecosystems

Impacts to the Resource:

Climate change can directly and indirectly affect soil fertility, plant growth and decomposition in forest ecosystems. Climate can also be implicated in the frequency and severity of disturbances like wildfires, pest outbreaks and spread of invasive species.

Rising temperatures increase insect outbreaks in a number of ways. First, warmer winters allow larger populations of insects to survive the cold season that normally limits their numbers. Second, the longer warm season allows them to develop faster, sometimes

15 U.S. Environmental Protection Agency (2012a)
16 EEEA and the Adaptation Advisory Committee (2011)
17 Ramsar (2002)
18 MCCC (2010)
19 Ramsar (2002)
20 Frumhoff et al. (2007)
21 EEEA and the Adaptation Advisory Committee(2011)
22 Frumhoff et al. (2007)
23 USGCRP (2009)

completing two life cycles instead of one in a single growing season. Third, warmer conditions help expand their ranges northward. And fourth, drought stress reduces trees' ability to resist insect attack (for example, by pushing back against boring insects with the pressure of their sap). Spruce beetle, pine beetle, spruce budworm, and woolly adelgid (which attacks eastern hemlocks) are just some of the insects that are proliferating in the United States, causing devastation in many forests. These outbreaks are projected to increase with ongoing warming. Trees killed by insects also provide more dry fuel for wildfires.[24] Further, the increasing carbon dioxide concentration stimulates the growth of most plant species, and some invasive plants respond with greater growth rates than non-invasive plants. Beyond this, invasive plants appear to better tolerate a wider range of environmental conditions and might be more successful in a warming world because they can migrate and establish themselves in new sites more rapidly than native plants.[25]

The growing season is lengthening over much of the continental United States. Scientists have very high confidence that the earlier arrival of spring events is linked to recent warming trends in global climate. Disruptions in the timing of these events can have a variety of impacts on ecosystems and human society. For example, an earlier spring might lead to longer growing seasons and more abundant invasive species and pests.[26] Leaf growth and flower blooms are examples of natural events whose timing can be influenced by climate change. Observations of lilacs and honeysuckles in the contiguous 48 states suggest that first leaf growth is now occurring a few days earlier than it did in the early 1900s.[27]

Impacts to Species:

Climate change will cause changes in species composition and distribution for both plants and animals. For trees, climate variables affect where they can grow, growth rates and ecosystem functions like water and nutrient cycles. Suitable habitat for tree species will shift northward, by as much as 500 miles by 2100 under the high emissions scenario, or by 350 miles under the lower scenario.[28] Historically, forest types have shifted at the range of 12 to 15 miles every 100 years.[29] Species moving northward and to higher elevations to stay within optimal temperature ranges are invading new habitats. Some mountain tree species have shifted uphill by 350 feet in the last 40 years.[30] Even if some or most northern hardwood forests are able to persist, there will be increased competition and replacement from migrating southern species.[31] While common species such as maples may decline in abundance and oaks may increase under climate change, more vulnerable species such as spruce may be extirpated from portions of the state or their distribution may be significantly reduced.

Changing climate factors and forest types will also likely alter the composition and role of other species such as song birds, forest floor plants, and invertebrates, as well as disrupt predator-prey relationships, wildlife migration corridors, and alter phenological patterns and other, often complex, ecological processes. Every species will react to these impacts in different ways, leading to potential community disruption as plants and their pollinators or predators and their prey are "pulled apart." The ranges of many species in the United States have shifted northward and upward in elevation.[32] In the United States, for example, a number of butterfly species have shifted northward and contracted upward in elevation over the last century.

Climate changes create stresses for both plant and animal species by shifting timing of seasons, in turn affecting blooming and reproduction and altering patterns of feeding and pollination. Some birds like tree swallows now begin egg-laying over a week earlier than in the past, which could mean young may hatch before insect food is plentiful for some species. Isolated vernal pools that serve as breeding areas for some frogs and salamanders

24 USGCRP (2009)
25 USGCRP (2009)
26 U.S. Environmental Protection Agency (2012a)
27 U.S. Environmental Protection Agency(2012a)
28 Frumhoff et al. (2007)
29 EEEA and the Adaptation Advisory Committee(2011)
30 USGCRP (2009)
31 Frumhoff et al. (2007)
32 USGCRP (2009)

and very susceptible to changes in the timing of precipitation. If these pools were to disappear earlier in the spring, it could severely disrupt frog populations.[33]

Many migratory bird species are arriving earlier. For example, a study of northeastern birds that migrate long distances found that birds wintering in the southern United States now arrive back in the Northeast an average of 13 days earlier than they did during the first half of the 20th century. Some birds shift their range or alter their migration habits to adapt to changes in temperature or other environmental conditions. Long-term studies have found that bird species in North America have shifted their wintering grounds northward by an average of 35 miles since 1966, with a few species shifting by several hundred miles. On average, bird species have also moved their wintering grounds farther from the coast, consistent with rising inland temperatures.[34]

Other Ecosystem Services

Ecosystem services is the name for a variety of activities and functions provided by ecosystems that serve to provide, support or regulate various other natural systems or human activities, health and economies. Many of these services are already in decline due to stresses like development and contamination, so are likely to be less resilient to additional stresses caused by climate changes.[35] A recent assessment reported that of 24 vital ecosystem services were being degraded by human activity.[36]

Upland forests provide important functions including support for a variety of habitats and wide-ranging biological diversity, filtering and purification of air and water, moderation of subsurface and overland water flow, streambank stabilization, and the sequestration of carbon in both the above-ground growing vegetation and in the organic components of forest soils. In addition, forests provide scenic, recreational, and tourism benefits and a rural quality of life for many citizens. Upland forests also provide energy to streams in the form of organic material. A greater frequency of extreme storm events and subsequent flooding can increase erosion and threaten streambanks and riparian areas. Also, if increased pests, disease and drought threaten forest integrity, the protection, filtration and shading provided by forests could be compromised and lead to degraded water quality in some areas.

In terms of eco-recreation, sea-level rise and storm surges may reduce publicly accessible beach areas while at the same time, the demand for beach recreation to escape the heat will be increasing. Other activities likely to be harmed by even small increases in temperature are snow- and ice-dependent activities like skiing, snowmobiling, and ice fishing.[37] Carbon storage capacity is lost when marshes and wetlands erode or disappear, as well as water filtration services provided by wetlands. Tidal wetlands provide mitigation from storm surges and flooding, and inland wetlands soak up runoff from heavy rains and snow melts, providing natural flood control. Wetlands also release stored flood waters to streams during droughts.

New Jersey Specific Impacts

Climate change will compound existing ecosystem stressors in New Jersey include destruction and fragmentation due to land development, invasive species, deer browsing, pollution, storms and fire.[38] Of the aforementioned risks to natural resources, there are two that are of particular concern to areas in New Jersey. Loss of wetlands, particularly coastal wetlands, is a critical issue in the state, as sea level rise combined with higher storm surges threatens to reduce wetlands acreage, affecting habitat and also the buffering and protection they provide for coastal communities. Also, because of its geographical position in the midrange of the Atlantic coast, pronounced impacts are likely to occur in the composition of plant and wildlife species, as some native species will decline or migrate, and new species will migrate in.

33 MCCC (2010)
34 U.S. Environmental Protection Agency (2012a)
35 USGCRP (2009)
36 Millenium Ecosystem Assessment (2005)
37 USGCRP (2009)
38 MCCC (2010)

Table 1: New Jersey Impacts and Risk for Natural Resources as a result of climate change

Climate Impacts	New Jersey Risks
Sea Level Rise	• Loss of wetlands and associated habitat functions • Loss of beaches and associated habitat functions
Extreme Weather Events	• Erosion or destruction of habitat
Warming Temperatures	• Changes in forest habitat • Increased forest pests • Increased and more severe wildfires • Changes in salinity, circulation, and temperature affecting estuarine structure, species health and distributions and migratory routes
Ocean Acidification	• Acidification impacts calcifying species such as shellfish and plankton putting the food web at risk.

Sea Level Rise:

Among the most most vulnerable habitats are those located in swamps or marshes.[39] Sea level rise is a major threat to tidal wetlands in New Jersey. The region is already seeing sea levels rising 3-4 mm per year in the last century, up from 1 mm/year in the prior millennium.[40] Increases in the mid-Atlantic region are expected to be greater than global average increases in the coming decades. Using the SLAMM model researchers have predicted the loss of one tenth of tidal wetlands in the Delaware Estuary by 2100.[41] Najjar and co-authors (2000) predict that 21 percent of mid-Atlantic wetlands (which includes New Jersey) will disappear by 2100.

In New Jersey, evidence suggests accretion will not keep up with SLR. Even if natural migration were able to occur, many coastal wetlands are blocked from inland migration by human development or infrastructure.[42] A 1.22 m rise in sea level by 2100 could inundate about 30% of saline marshes in NJ (see Table 2).

Loss of beaches and dune areas from sea level rise will also result in reduced habitat for many coastal species, as noted in under "extreme weather impacts." In addition to inundation from rising seas, coastal systems that are dependent on particular levels of freshwater infiltration are likely to suffer negative impacts, as more frequent and prolonged periods of drought, combined with more intense use of water by humans, can be expected to alter river flows.

Extreme Weather Events

Coastal wetlands often help to buffer coastal communities from effects of storms, but severe storm events themselves are another threat to wetland systems for a number of reasons. While any one storm, such as Hurricane Sandy that hit New Jersey in October of 2012 cannot be directly tied to climate change, the changing sea temperatures and flows, and already higher sea levels that are widely viewed as factors tied to climate change served to intensify the storm. As seen during Hurricane Sandy, storm-driven water removed vegetation, moved millions of tons of sand and silt and exposed new open sand. This changed landscape likely eroded important habitat for many shorebirds, and many other important species like horseshoe crabs, but in other areas may also have created new nesting habitat for some birds like plovers and terns, or stopover areas for migrant birds.[43]

Storms can also cause an influx of excessive freshwater into saltwater systems, a phenomenon witnessed during Hurricane Irene. The lower salinity affects habitats and species that rely on the presence of freshwater to guide their migratory patterns.

New Jersey could see a substantial reduction in bird life, specifically in migratory songbirds, due to shifting habitat types and declining quality of habitat.[44] There is already some evidence that Hurricane Sandy impacted

[39] Park et al. (1989); Ramsar (2002)
[40] Kreeger et al. (2010)
[41] Kreeger et al. (2010)
[42] Cooper et al. (2005)
[43] Manomet Center for Conservation Sciences (2012)
[44] Frumhoff et al. (2007)

Table 2 : Wetland land use classes below 0.61m and 1.22 m sea level in New Jersey

Wetland Class	Land Area Below 0.61m contour (km²)	Land Area Below 1.22 m contour (km²)	Total Land Area in New Jersey (km²)
Saline Marsh	134.7	251.2	771.8
Freshwater Tidal Marsh	2.6	10.4	38.8
Interior Wetlands	5.2	18.1	1763.8*
Total	142.4	279.7	2574.4 636,134 acres

**represents only interior wetlands located in New Jersey coastal watersheds*
(Source: Cooper et al 2005)

bird species in New Jersey. Based on observations reported by bird-watchers in the region, some short-distance migrants moving down the coast were displaced by Sandy's high winds, and some seabirds were pushed inland. After Sandy, for example, Leach's storm-petrels appeared on lakes in upstate New York and Pennsylvania, and a Herald petrel, a bird that is typically far offshore, was found in Pennsylvania.[45] Also some active October migrants like the pomarine jaeger, that would be migrating offshore was found in unprecedented large numbers in Pennsylvania after the storm.

Finally, New Jersey's ecotourism value may be at risk as ecosystems are lost or changed. Impacts on bird species from lost or degraded habitat could result in fewer people coming to New Jersey for enjoyment of its abundant shorebirds and migrating songbirds. Eventual changes in forest composition could affect scenery and recreation.

Warming Temperatures

Plant and animal species that are native to New Jersey or migrate through New Jersey will be impacted by climate change, in combination with other stressors. Climate change will affect New Jersey forests in several ways. While there is no projected loss in total amount of forest land in the Northeast from climate change factors, the character of forests will change. In northern New Jersey, habitat for the maple-beech-birch and spruce/fir forests are expected to contract. Winter warming will reduce suitable habitat for hemlock and expand the habitat of the deadly hemlock woolly adelgid pest.[46] Forests also will experience a longer wildfire season and more fires, as temperatures rise and fire-prone tree species replace native species.[47]

In terms of animal species, temperature increases will especially affect coldwater species such as brook trout and lake trout.[48] In coastal areas, potential effects on bivalves are of particular concern as some, such as oysters, are critical to maintaining the health and structure of the habitat, in addition to acting as a source of food. Winter flounder populations are already decreasing due to over-fishing and warmer ocean temperatures will likely speed up this trend.[49]

Benchmark Adaptation Practices

The goal of adaptation is to reduce the risk of adverse environmental outcomes through activities that increase the resilience of ecological systems to climate change.[50] Adaptation strategies for natural resources and habitats include land and water protection (such as acquisition and easements), land and water management changes, increased agency cooperation and coordination, and enhanced and focused monitoring and research.[51] The Commonwealth of Massachusetts Climate

45 Kaufman (2012)
46 Frumhoff et al. (2007)
47 Brown et al. (2004)
48 Trout Unlimited (2007)
49 NOAA NEFSC (2006)
50 USCCSP (2008)
51 USCCSP (2008)

Change Adaptation Report of 2010 and the Maryland Commission on Climate Change's 2010 Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change are both examples of state-level comprehensive strategies that include a discussion of impacts to natural resources and recommendations and practices for protecting and strengthening ecosystems from climate change stresses. They both stress the key principles described below.

Core adaptation strategies are:

1. Protect representative ecosystems of sufficient size

Ideally, large unfragmented expanses of key ecosystems (forest, wetland, river, coastal) of high quality are protected permanently to increase resilience and support a diversity of species. Sufficient size is necessary so that the system can successfully absorb small perturbations. Protecting multiple examples in independent places ensures that at least some will persist. Acquisition of unprotected land should be targeted to vulnerable or critical areas, for instance areas upgradient from coastal wetlands.

Costs for direct acquisition of more public land for conservation could be prohibitive and unpopular, so stressing all of the natural resource values and functions provided by conserved land will be important for public support. Preserved ecosystems serve as "green infrastructure" that is a soft engineering and economical approach to preserving other economic and social values also.[52] As an example, a healthy coastal wetland can serve to reduce impacts of storm surge as an alternative to a hard engineering solution. The concept of a "living shoreline" is one that has been explored along the Atlantic seaboard and may be increasingly relevant in a future with more extreme weather events.[53] Also, climate change easements, incentives and technical assistance programs to foster stewardship and protection of resources held by private landowners can preserve the integrity of more natural landscapes beyond what governments can preserve. For example, the state of Maryland evaluates properties for conservation based on sea level rise resiliency.[54]

2. Protect connective corridors between ecosystems

Ecosystems and species are dependent on regional scale processes so it is important to provide connectivity across habitats to facilitate dispersal, migration, and maintenance of native species, and the regional movements of populations in response to changing climate factors.[55]

3. Promote species protection and resiliency

Based on vulnerability assessments, key habitat should be protected. Some areas should be refuge areas that are relatively safe from climate change impacts. Habitat enhancements such as constructed wetlands, oyster or mussel reefs can help to bolster resilience, where feasible. Recently, researchers in New Jersey recently constructed new breeding habitat for the state endangered Eastern Tiger Salamander that is outside areas at risk for sea level rise. During Hurricane Sandy in October of 2012, two of the ponds were inundated with water from adjacent salt marshes, and researchers have not yet determined how this will impact the species during breeding season.[56]

4. Limit ecosystem stressors

To improve resilience and full functioning, it is important to reduce non-climate change related threats such as habitat fragmentation (i.e., development), invasive species, and pollutants. Managing for reduction of these stressors will help ecosystems to be healthier and thus to respond better to climate-induced stresses.

5. Practice adaptive management based on ongoing scientific monitoring and assessment

Natural resource managers should develop flexible concepts for understanding natural systems, continually verifying management and adaptation decisions through assessment, modeling and long-term monitoring to better understand vulnerabilities and climate impacts on ecosystem dynamics. Effective management requires sufficient and accurate information. This could include tracking migratory pathways, developing models of coastal

52 EEEA and the Adaptation Advisory Committee (2011)
53 Kreeger et al. (2010)
54 (see http://www.dnr.maryland.gov/ccp/pdfs/MDCCPEForm_July2011.pdf).
55 MCCC (2010)
56 Golden (2012)

inundation, and water column temperature and salinity measurements. A particular need, for example, is to better understand the specific impacts and effects of changing conditions in estuaries, where climate change effects will be especially pronounced.[57] A good idea is to set up baselines in ecosystem functions or services and thresholds that should trigger interventions.[58] Specific programs to revise in preparation for climate impacts include riparian buffers, saltwater marshes, and upland/inland habitat where wetlands will need to migrate.[59] Fisheries management will need flexibility to accommodate species shifts.[60]

Also, flexible, climate-responsive regulations will also be critical to confronting climate change threats. For example, streamflow criteria may be adjusted to re-establish natural flow in rivers and streams to combat increased salinity[61,62,63] and floodplain maps may need to be updated to reflect changing climate realities. Managers could be required to strengthen consideration of cumulative impacts as influenced by climate change at project planning levels.

6. Collaborate on regional scale

Ecosystem managers need to collaborate closely across regions and political boundaries to study and manage habitats that cross jurisdictions and develop goals to help flora and fauna respond to climate change. The National Fish, Wildlife and Plants Adaptation Strategy, developed by a group of federal agencies, is a useful guide to foster a collective plan across state boundaries and across agency jurisdictions to manage natural resources for maximum health over the coming decades.[64] Also, natural resources managers need to work not just within government agencies, but involve other stakeholders of varied interests. Working together with businesses is a strategy to achievement of land preservation. In southern New Jersey, the Department of Environmental Protection has succeeded in preserving more than 5000 acres of wetlands and upland areas in the wetland migration path through direct collaboration with local industries.[65]

Some examples of programs, in addition to the state-level approaches in Maryland and Massachusetts, incorporating one or more of these strategies include:

California Climate Adaptation Strategy[66]

The plan includes a statewide study of implications of SLR, and a requirement for the state Natural Resources Agency to work with other governments and businesses to create a state Climate Adaptation Strategy, including biodiversity and habitat, and ocean and coastal resources. Recommendations included identification of key habitats at risk and plans for expanding protected areas.

Greater Yellowstone in Peril: The Threats of Climate Destruction[67]

This ecosystem-based plan incorporates climate change into natural resource conservation and management. A group of experts translated climate change projections into a set of adaptation strategies such as identifying intervention points for managing snowpack, vegetation structure, improving connectivity or managing animal populations.

US EPA National Water Program Strategy: Response to Climate Change[68]

This 2012 Strategy builds on the first strategy document published in 2008 with a set of long term goals for the management of sustainable water resources for future generations in light of climate change. It charts the key 'building blocks,' i.e., strategic actions that would need to be taken to achieve those goals including protecting habitat corridor networks, expanding wetlands mapping and preparing for changes in ocean water quality.

57 EEEA and the Adaptation Advisory Committee (2011)
58 USGCRP (2009)
59 MCCC (2010); Kreeger et al.(2010)
60 Caridad and Able (2012)
61 Kreeger et al. (2010)
62 MCCC (2010)
63 EEEA and the Adaptation Advisory Committee (2011)
64 Shaffer, Griffis and Barnhart (2012)
65 Cooper et al (2005)
66 California Natural Resources Agency (2009)
67 Saunders et al. (2011)
68 U.S. Environmental Protection Agency (2012b)

Discussion and Recommendations

Key messages about climate change and natural resources are that climate change will compound existing environmental stressors for natural resources, and that policies to manage natural resources must adjust to a changing climate to be effective. New Jersey should look at all six of the core strategies listed above to consider enhancing or adding climate change considerations to improve the resiliency of its natural resources and key ecosystems.

New Jersey should continue to support science and research in areas that will create more certainty in impact or prioritization when evaluating programs and decision making capability to support given policies. There are also certain areas where New Jersey has experience with understanding the risks of climate impacts. New Jersey just witnessed the damage or destruction of managed wetlands and small islands critical to nesting seabirds and migrating shorebirds. Damage assessments have not yet been conducted, but the impact of the storm on important habitats belies the need for detailed assessment surveys of waterbird habitats to help identify critical needs and management options that may not be obvious.[69] In those cases, it is important for the state and other stakeholders to being to develop policies and evaluate investments in technologies that will help residents and businesses adapt to changes in our climate.

In New Jersey, both the Garden State Preservation Trust and Green Acres programs can be used to purchase threatened wetland areas and undeveloped buffers between wetlands and development. Other funding mechanisms that could be directed to preserving climate change sensitive or "refuge" areas to save priority species are the Environmental Infrastructure Trust or Blue Acres. These programs could be adapted into a new "green" or "climate ready" infrastructure trust fund. The critical role of conservation organizations in preserving and managing critical natural areas needs to be fostered and encouraged. To achieve protection on private lands, a regulatory program requiring the gradual withdrawal of development, a rolling easement, from the migrating coastline could be effective. A gradual withdrawal of development from the shoreline could allow natural systems to migrate inland.[70] In addition to the aforementioned policies, the Alliance has compiled a series of potential areas for investigation and consideration in Table 2.

Table 3 : Specific areas for investigation based on leading practices [71]

New Jersey Adaptation Need	Potential Initiatives for Investigation and Projects
Understand vulnerability and resilience of natural resources to climate change	• Ocean observation and long-term monitoring of physical, biological and chemical conditions. • Early warning and notification systems for shellfish closures, or unusual events like hypoxia. • Through geomorphic assessment, identify vulnerable river reaches and monitor rivers for disconnection from floodplains. • Update Federal Emergency Management Agency (FEMA) floodplain maps to reflect current conditions and predictions of future conditions. • Identify vulnerable river reaches, establish and protect belt-width-based river corridors, restore floodplains, and increase use of bioengineering techniques for bank stabilization • Identify and protect remaining critical coldwater fish habitat areas and seek to reconnect high quality habitats by removing in-stream barriers and re-establishing in-stream flows • Identify and implement strategies for early detection, rapid response, and prevention of invasive exotic plants and animals that out-compete native species and gradually reduce the diversity of species composition

69 Manomet Center for Conservation Sciences (2012)
70 Cooper et al. (2005)
71 Modified and expanded from NJDEP (2009), Frumhoff et al. (2007), USCGRP (2009), ARWG (2011), NYSERDA ClimAID Team (2010), PDEP (2011), EEEA and the Adaptation Advisory Committee (2011).

Integrate Climate Adaptation with Planning and Regulation Processes	• Create a consortium for coordination of research, data sharing and leading practice dissemination • Manage for biodiversity and age diversity, and special protection for sensitive species. • Identify and protect representative ecosystems of sufficient size while strengthening state and local programs to slow the loss and fragmentation of terrestrial and/or aquatic ecosystems to new development • Consider establishing landowner incentives for forest ecosystems including forest management incentives or tax credits for the preparation of forest management plans • Provide funding for technical assistance to implement smart growth and reduce development footprint on forests, mitigation requirements for forest conversions • Evaluate sustainable forestry certification programs for opportunities to enhance climate resilience and adaptive capacity • Expand use of ecological solutions to sea level rise, examining the benefits of shifting from engineering-based and infrastructure-focused solutions toward a union of engineering and ecological planning • Consider developing more flexible conservation regulations that take into account potential sea level rise and changing floodplains • Extend planning of coastal areas beyond the state and federal agencies and involve other stakeholders to ensure representation of varied interests • Explore strategies to improve protection of buffer zones around vulnerable wetlands and vernal pools, potentially through conservation easement mechanisms to promote adaptation stewardship activities on private lands • Foster and promote opportunities to develop new emerging ecosystem service markets such as carbon sequestration and biomass-based fuel production • Prepare for new or expanding ranges of invasive species, potentially through: ballast water regulations; cleaning and transportation practices for boats; banning the sale of invasive plants and animals; increasing monitoring and control of invasive marsh and coastal plants; and cleaning of machines to remove seed or root cuttings before moving to a new site • On-site tree preservation percentage requirements for new development consistent with tree canopy target recommendations of American Forests

Invest in technology adaptation to encourage resilience	• Use natural shorelines, setbacks and buffer zones to allow inland migration of shore habitats over time. (dunes and buffers mitigate storm damage) • Remove hardening of coastline so that sand and vegetation can migrate naturally, restore or create coastal wetlands • Manage for drought-tolerant species in areas of drought • Purchase wetlands to provide refuges and enhance flow. • Plant flood-adapted species along rivers to reduce erosion • Reforest riparian areas with native species for refuges from heat for fish • Encourage application of geotextiles and bioengineering techniques for erosion control and stream stability • Identify climate change refuges and use "insurance factor" to buffer areas and account for uncertainty • Protect migration corridors to allow as natural adjustment as possible • Consider establishing a fire management council to facilitate prescribed fire management in fire-adapted pitch pine/scrub eco-systems on a landscape scale. • Use land acquisition and conservation restrictions to target protection of vulnerable intermittent headwater streams and their buffer areas. • Establish seed banks and preserve species in zoos or gardens • Allow natural fires to burn where they sustain ecosystem integrity and restore natural disturbance regimes. • Increase timber production by identifying and selecting carbon dioxide-responsive tree species; regionally coordinated monitoring and rapid response eradication of invasive species • Regionally coordinated monitoring and rapid response control or containment of insect pests and invasive species • Maintain coldwater refuges through shading and by maintaining groundwater flows • Facilitate dispersal, with monitoring and containment of undesirable species; wildlife disease surveillance • Monitor and modify hunting seasons and bag limits to control or reduce deer populations • Infrastructure planning to maintain water supplies to high priority regions • Identify and assess potential restoration of coastal wetlands or alternately, identify, assess and mitigate existing impediments to inland migration of coastal wetlands

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