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January 10, 2020

The Effects of Climate Change in New Jersey

As climate change is one of the most pressing issues affecting society today, it is important to consider the changes to our ecosystem that it has caused in order to best prepare for its future effects. New Jersey, being one of the states most disproportionately affected by climate change as measured through increases in temperature, the extent of extreme weather, and impacted homeowners, will see the effects of climate change occur at a more rapid pace than most other states (Gil-Alana & Sauci, 2019; Solecki et al, 2005). The effects of climate change in New Jersey may be observed through evaluating the changes in rising sea levels and extreme weather as well as what current actions are taken to mitigate those effects and how to plan for the future.

Rising Sea Levels

Rising sea levels occur as a result of the thermal expansion of ocean water, mass loss from glaciers and ice caps, changes in land water storage, and the increased use of fossil fuels (Kopp et al, 2016). Increased usage of fossil fuels results in the release of additional carbon dioxide into the atmosphere which traps heat by preventing the escape of solar radiation into the atmosphere (Kopp et al, 2016). In New Jersey, according to a Rutgers University study, sea levels along the coast have risen 1.5 feet from 1911 to 2019, which is over double the global average of 0.6 feet (Gralish, 2019). Further, the same study predicts rises of up to 2.1 feet by 2050, 3.5 feet by 2070, and 6.3 feet by 2100 (Kopp et al, 2016). Various studies have shown that rises of even the current 1.5 feet can have large impacts on vulnerable communities along the

coast, including Atlantic City (Kopp et al, 2016). Thus, climate change and the forecasted sea level rise will put New Jersey businesses, homes, and entire cities at risk of flooding and becoming uninhabitable throughout the current century. Due to this, New Jersey homeowners were found to be the most at risk from climate change when looking at the proportion of at-risk homes in a given state compared to the total number of homes, along with Delaware and Louisiana homeowners ("New Jersey, Delaware and Louisiana," 2019).

Additionally, current models predict sea levels to rise nationally. Models show a 90% probability that sea levels will rise globally between 0.3-1.8m by 2100, occurring as a result of thermal expansion of ocean water and changes in land water storage (Kopp et al, 2014). For New Jersey, it is projected that coastal areas will experience sea level rises with a 67% probability of 0.6-1.0 foot per year by 2030, but only and a 5% probability that sea levels will rise over 1.1 feet by 2030 and 2.0 feet by 2050 (Kopp et al, 2014). Rutgers' report also predicts sea levels rising between 1.4 and 3.1 feet from 2000 to 2070 if greenhouse emissions are not reduced, and additionally that sea levels are rising at a fast rate (Kopp et al, 2016). Thus, New Jersey is experiencing sea levels rising as a faster rate than the national average. Additionally, these higher sea levels will increase the effects of coastal storms by increasing the baseline for flooding.

Sea levels are also rising at rates higher than previously predicted. While previous estimates accounted for a 0.5 mm per year rise in sea levels since 2000, there has instead been a consistent rise of 1.8 mm per year (Miller et al, 2009). Consequently, predictive models consistently underestimated the rise in sea levels. Further, studies have shown that rising sea levels in New Jersey were underestimated by about 0.5 m due to rapid increases between 9,000 and 8,000 years (Horton et al, 2013). In addition, there is a 99% probability that sea levels rose faster in the twentieth century than any other in the past 3,800 years (Miller, Kopp, Horton,

Browning, & Kemp, 2013). The underestimation of rising sea levels has continued to influence predictions today in New Jersey, which continue to be higher than anticipated.

Rising sea levels contribute to higher levels of coastal flooding in New Jersey. Since 1980, sea levels in New Jersey have risen by nearly six inches, increasing the risk of tidal flooding by at risk homes by 110% and the frequency of storm surges (Johnson, 2019). For example, a projected 1-foot increase in sea level would result in portions of Toms River, NJ being submerged and portions of Ocean Gate, NJ and Point Pleasant Beach, NJ being underwater (Kopp et al, 2016). This flooding also puts New Jersey's wetlands at risk. In a case study of Cape May, New Jersey, findings showed that rises in sea-level will result in increased vulnerability and exposed areas to flooding hazards (Wu, Yarnal, Fisher, 2002). Five to seven feet rises in sea levels may result in about 80% losses in the state (Titus et al, 1988). As sea levels are projected to rise up to 6.3 feet by 2100, this loss in wetlands is feasible in the near future. Further, these risks are projected to grow in New Jersey and extend beyond just the predominantly affected coastlines (Johnson, 2019). This increased risk of flooding is due to sinking land along the coast, resulting in increased flooding due to precipitation and high tides (Kopp et al, 2016).

Rising sea levels may cause additional issues such as economic issues that disproportionately affect at risk areas along the coast (Kopp et al, 2016). For example, economic impacts stemming from rising sea levels may be observed through higher costs of production, elevation, and abandonment of properties (Hudgens, Herter, & Martinich, 2010). Additionally, national studies have found that large-scale climate events have posed health-related costs that total $10.0 billion and mortality costs exceeding the combined cost of illness and lost wages (Limaye, Max, Constible, & Knowlton, 2019). These findings result from a 2012 analysis that covered cases of observed climate change from 11 U.S. states ranging from wildfires in Colorado

and Washington to extreme heat in Wisconsin and even Hurricane Sandy in New Jersey (Limaye, Max, Constible, & Knowlton, 2019). Specifically in New Jersey, it is projected that damage due to coastal flooding and wind will rise to between $1.3 billion to $3.1 billion (Johnson, 2019). These economic challenges extend to reduced property values as New Jersey has seen sea-level rises reduce home values by $4.5 billion in the past four decades (Johnson, 2019). Further economic challenges resulting from climate change are expected to produce financial losses of up to $660 million in yearly losses, specifically in both Hudson and Bergen counties in New Jersey (Johnson, 2019). This shows that in order to avoid damage to state economies, especially coastal states such as New Jersey, measures must be taken to mitigate the effects of climate change.

Extreme Weather

In addition to rising sea levels, New Jersey has been subject to intensifying extreme weather patterns due to climate change. More frequent and more intense extreme weather is caused by higher amounts of moisture being present in the atmosphere as a result of increased greenhouse gases (Byers, 2019). This extreme weather will likely lead to heavier precipitation and an increased risk of flooding, especially in areas with already high levels of precipitation, with this trend projected to continue (Trenberth, 2011). New Jersey will experience increased frequency elevations of 100-year events, occurring at least every eight years instead of every 30 years in other northeastern states (Kirshen et al, 2008). In turn, this will result in higher annual economic costs in relation to damage done by extreme weather conditions such as hurricanes (Johnson, 2019). New Jersey has already experienced weather patterns that are increasingly extreme than in previous centuries. Events such as Hurricane Sandy in 2012 set records for peak-water levels in parts of New Jersey (Hall & Sobel, 2013). In 2018, New Jersey had 64.79 inches

of rainfall, meaning the state experienced levels of precipitation 18.43 inches above the statewide normal without the presence of a major tropical storm (Byers, 2019).

Shore erosion has become an increasingly common effect of climate change in the state of New Jersey as a result of both rising sea levels and intense storms (Lorenz, Shadel, & Glick, 2017). Current trends have suggested that a sea level rise of 1 foot may contribute to a shoreline erosion of up to 120 feet (Lorenz, Shadel, & Glick, 2017). While erosion in New Jersey has experienced high rates of variability, complex differential resistance patterns and irregular shoreline configurations affecting shoreline exposure to wave energy impact levels of shore erosion the most, as shown by a case study of Delaware Bay, New Jersey (Phillips, 1986). In an attempt to best combat this issue in the short-term, sand dunes in New Jersey have historically faced large levels of human modification. This involves modifying the size and shape of dunes in relation to the level of perceived threat from coastal winds and the level of defense needed (Nordstrom & Arens, 1998). Further, coastal New Jersey has been found to be the most vulnerable to shoreline erosion out of states in the Northeast (Karmeshu, 2012). This is due to increasing trends in precipitation which result in higher levels of coastal flooding (Karmeshu, 2012).

Extreme temperatures have also become increasingly prevalent in New Jersey due to an increase in paved surface in the state (Lorenz, Shadel, & Glick, 2017). Among other Northeastern states, New Jersey has experienced an increasing trend in warmer temperatures since 1901 (Karmeshu, 2012). New Jersey recorded one of the highest temperature increases in the country between 1895 and 2017, with temperatures rising about 2.9°C over the past 100 years (Gil-Alana & Sauci, 2019). Additionally, temperatures in New Jersey are projected to increase by between three- and ten-degrees Fahrenheit by 2100 (Byers, 2019). Accordingly,

since 1985, New Jersey has had nine out of the state's 10 warmest summers in the past 20 years (Byers, 2019). Within the trend of rising temperatures within the state, an additional sub-trend of the Urban Heat Index and "Heat Island Effect" may also be observed. This effect is observed in metropolitan areas within the state such as Newark and Camden where high temperature, low cloud cover, and low wind speeds intensify that heat within the area (Rosenzweig, Solecki, Parshall, Chopping, Pope, & Goldberg, 2005). Temperatures have already been shown to be higher in Newark and Camden in comparison to nonurban communities in New Jersey by 1.5-3°C with a projected continuation in the future (Rosenzweig, Solecki, Parshall, Chopping, Pope, & Goldberg, 2005). With higher temperatures in Newark and Camden, heatwaves are projected to become increasingly likely and result in higher levels of mortality than other areas in the state (Rosenzweig, Solecki, Parshall, Chopping, Pope, & Goldberg, 2005). Suggestions to mitigate this effect have included increased vegetative cover and higher-albedo surface materials that reduce the impacts of biohazards in urban areas, in order to reduce elevated temperatures, air pollution, and public health effects (Solecki et al, 2005).

Responses to Climate Change

As a result of the previously mentioned implications of climate change such as rising sea levels as well as coastal flooding and erosion, inhabitants of New Jersey must begin to migrate inland. Despite federal recovery grants intended to be given to individuals to restore their homes and elevate their houses to avoid flooding and new damage in the future, many individuals in New Jersey have instead looked to governmental "buy outs" such as through the Blue Acres program (Schwartz, 2019). This program would allow the government to buy the property at its pre-storm value, which transfers the deed to the state in order to demolish the house and block redevelopment in the future (Schwartz, 2019). Further, rising sea levels and coastal flooding in

New Jersey have led to buyouts that have contributed to inland migration. Specifically, in Woodbridge Township, New Jersey after superstorm Sandy, 142 homeowners accepted buyout offers, making it one of the largest buyout projects and proving the programs popularity (Schwartz, 2019). However, this program tends to be costly as it has already cost $172 million for the accepted buyout offers of 713 homeowners (Schwartz, 2019). Moreover, the most common response to rising sea-levels by barrier-islands involved pumping sand into the beaches and building lots in order to raise the islands and a possible retreat inland (Titus, 1988).

Additional responses to climate change along the coastline include measures such as adding sand onto beaches to gradually raise the placement of barrier islands, using levees and bulkheads to protect highly developed areas from rising sea levels, and the loss of undeveloped areas such as coastal wetlands (Titus et al, 1991). Coastal communities have even become as creative as utilizing old Christmas trees to build sand dunes at Island Beach State Park to create temporary and low-cost solutions to address rising sea levels and flooding (Wise, 2020). However, these responses may often produce unintended negative consequences. For example, the continual utilization of levees and bulkheads would slowly reduce and eventually erode wetland shorelines (Titus et al, 1991). Thus, while utilizing these responses may currently be cost-effective by preventing rises in sea levels that destroy highly valued property along shorelines, these responses pose long-term consequences that would reduce and/or eliminate coastal wetlands.

Plans have been put in place in order to mitigate some of the consequences discussed earlier concerning climate change in New Jersey. For example, the state government introduced plans such as the N.J. Coastal Resiliency Plan 2019 to reduce coastal flooding, improve awareness of coastal hazards, create consistent guidance for resilience, and guide easier

adaptation in the state ("NJ Coastal Resiliency Plan," n.d.). The Department of Environmental Protection leads these initiatives through their evaluation of policies and regulations at the state levels to reduce risk and increase coordination at a state-level ("NJ Coastal Resiliency Plan," n.d.). Further, the Bureau of Climate Resilience Planning provides support to communities within New Jersey to coordinate programs and inform communities to implement policies and programs that reduce the impacts and hazards of climate change such as building sustainable communities, protecting shorelines, and building solutions to coastal hazards ("Bureau of Climate Resiliency Planning," n.d.).

Recommendations

In order to combat rising sea levels and the various risks associated with it, New Jersey must prepare through planning, mitigation, and adaptation. While prevention efforts like reducing global emissions will be effective long-term, New Jersey must also focus on short-term solutions to save its coastal communities. One of these short-term solutions to prevent flooding may be to move housing developments away from high-risk areas (Johnson, 2019). Improved models that allow for flooding to be detected in real-time may allow for other consequences of flooding to be offset as well (Jordi et al, 2019). For example, the high-impact, high-resolution system (HIHR) used in the New York-New Jersey metropolitan region allows forecasts to show a "good agreement" with observations up to three days before peak flooding for the 95th percentile (Jordi et al, 2019). This allows for increasingly accurate forecasts ahead of major flooding incidents, which may be used to prepare for these events and offset damages. Additionally, software such as NJFloodMapper has been used to evaluate the impacts of flooding in New Jersey under different levels of rising seas (Lathrop, Auermuller, Trimble, & Bognar, 2014). The software evaluates exposure to coastal flooding after extreme weather and help target

audiences understand data such as rising sea levels, exposure to coastal inundation, and the vulnerability of different parts of given communities in order to help them best make decisions in relation to coastal preparedness (Lathrop, Auermuller, Trimble, & Bognar, 2014).

The effects of climate change in New Jersey may be observed through evaluating the changes in rising sea levels and extreme weather as well as what current actions are being taken to mitigate those effects and how to plan for the future. Further, as coastal areas will be most affected in the near and foreseeable future, it is important to focus efforts in those areas. Overall, the growing effects of climate change may likely result in an eventual inland migration of citizens living in coastal areas due to the high costs of other mitigation efforts.

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