

Chapter 8: Urbanization, climate change, and urban biodiversity

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The objective of this chapter is to assess the connection between ongoing global urbanization, climate change, and urban biodiversity. It is recognized that urbanization and its environmental consequences along with climate change will lead to increased risk exposure and vulnerabilities for urban biodiversity. Understanding urbanization, climate change risk, and vulnerability distribution is critical for effective climate change adaptation (Rosenzweig et al. 2010; Romero Lankao and Qin 2011; Seto and Satterthwaite 2010; Güneralp and Seto 2008), promotion of sustainable urban habitats and transition to increased urban resilience (Solecki 2012; Solecki et al. 2012).

Urbanization is one of the key drivers of global environmental change, and is directly connected to the ecological underpinning of urban life (Huang et al. 2010). An “important aspect of achieving urban sustainability is strengthening our ability to respond to the changing relation between urbanization and climate” (Grimm et al. 2008). As cities grow and change, the demand for resources expands and transforms increasing the cities’ ecological footprint and long distance resource linkages (e.g., teleconnections). In many cases, city-resource supply connections have become more distant and fragile (e.g., Seto et al. 2012; Darrel and Larsen 2006).

8.1 Framing and Outline

Several framing elements will be referenced in the chapter to foster understanding of the connections between urbanization, climate change, and biodiversity. These framing elements include ecosystem health, species habitat, and ecosystem services. Ecosystem health relates to the functioning of an ecological system at a level necessary to maintain and protect existing critical activities and operations for the short- and long-term. An important component of an ecosystem’s health is the maintenance and structure (e.g. species richness and species diversity) of a given region or biome (including flora and fauna). The supply and quality of natural water flow regimes associated with ecosystem health can vary significantly via seasonal and year-to-year changes.

Species habitat can be defined as the location where an organism, biological community or population lives or occurs. Habitat quality can be specified through a series of metrics including net primary productivity (e.g. volume of biomass produced per area), breeding effectiveness, and vulnerability to extreme events. Within a geographic area, several categories of habitats can exist, including signature habitats (e.g. those that represent a large percentage of the areal extent). Species habitat, in comparison to ecosystem health, focuses on the viability of a site for plant and animal habitation and reproduction.

A variety of urban habitats can be defined based on environmental, location, and hydrologic parameters. Wetlands, marine ecosystems, forests and other green spaces including lawns, beaches, and open fresh water and riparian buffers are valuable ecosystems within cities and their suburban metropolitan regions. Although defining the value of ecosystems in cities is analytically difficult, assessments have proved useful for determining relative service values for different ecosystem types, and to identify potential direct and indirect losses associated with environmental change.

Increasingly, cities and urbanization are being defined as opportunities for green economic development. The presence and profile of a green economy within a particular locale is at least partially defined by the local ecological potential. All cities are built on sites which present natural opportunities and challenges for development and green economic benefits. Urban design and development processes during much of the 20th century did not focus on catalyzing the natural systems within cities and indeed often ignored or sought to override them with modern engineering ‘solutions’. Contemporary principles increasingly focus on utilizing natural lighting, cooling, heating, and energy generating capacities in cities. In other cases, neglected or remnant ecological function more and more are being analyzed as opportunities for green economic development. In New York City for example, water flow and tidal cycles in local waters are being reviewed as sites for potential renewable electric power generation, while several noteworthy multi-purpose ecosystem-service initiatives are under way.

The chapter is built on the assessment of direct impacts of climate change which shift the risk and vulnerability profile of urban areas. The text is organized into the following sub-sections and topics. Section 2.0 introduces the conditions and process of contemporary urbanization,

urban livelihoods, and the prospects for future growth. Section 3.0 assesses how climate change will alter the climate regime of cities and resulting direct impacts. Section 4.0 focuses on how these shifts and impacts connect to the exposure and sensitivity of urban biodiversity and ecosystem services. The next section focuses on a critical climate change – urban biodiversity issue – the increased stress and loss of inland and coastal wetlands. A short summary and conclusion section completes the chapter.

8.2. Urbanization and Climate

The increasing concentration of the world's population, GDP and assets in urban centers is anticipated to have profound impacts on the local biodiversity of cities. The conditions of urbanization vary widely throughout the world. The factors that influence these conditions include the 1). competence, capacity and accountability of its government; 2). proportion of the population with incomes too low to afford food and non-food needs; 3). extent to which the whole population (and vulnerable groups within this population) are served by the basic infrastructure and network of services that should serve to maintain or reduce the level of risk; and 4). extent to which the city is physically at risk from climate change impacts. Variation of these factors have important consequences both for the process of climate change and how cities might be able to respond to climate change (Rosenzweig et al. 2011; Seto and Satterthwaite 2010; Güneralp and Seto 2008).

Urbanization has key qualities and parameters (spatial, temporal, and sustainability) which connect to the shifting, complex interactions between climate change and urban growth within a global-regional context. Given the significant and rising levels of urbanization, more people will be exposed to impacts of climate change due to not only the increase in number of population living in urban areas but also due to an increase in megacities (de Sherbinin et. al. 2007, Revi 2007). Additionally, smaller urban centers in Africa, Latin America, and Asia are growing rapidly but are frequently institutionally weak and unable to promote effective mitigation and adaptation actions (Romero-Lankao and Dodman 2011). It is in the smaller cities, of 1 million or less, where most population growth is expected to be a challenge to adaptation and mitigation as elements of urban development.

Urbanization alters local environments via a series of physical phenomena (e.g., heat islands, hydrologic) that are exacerbated with climate change. It is critical to understand the interaction between the urbanization process, current local environmental change and

accelerating climate change. For example, the intensity of urban heat island (UHI) conditions have been found to be associated with the extent and level of urbanization (e.g., Kolokotroni et al. 2011; Chen et al. 2011; Iqbal et al. 2011 as recent examples). Under favorable conditions, dense, large cities can be more than 10°C warmer than surrounding rural environments (Oke 1982). Significant research has been done to link recent climate shifts and extreme weather events and rates of urbanization with linkages to on-going and future climate change (Manton 2010). Climate change in New York City for example is expected to exacerbate the existing UHI conditions via increase of extended heat waves (Rosenzweig et al. 2009).

The results of computation modeling exercises indicate an ‘urban effect’ that leads to locally higher temperatures and reduced humidity, with additional warming also marginally increasing rainfall over large cities (Grimmond et al. 2012). This condition illustrates how building material properties are influential in creating different urban climates, which have the potential to alter the surface energy balance in cities (Jackson et al. 2010; Oleson et al. 2011). Results suggest that cities can adapt and mitigate climate change if redesigned with new more energy-efficient building materials, increased used of pervious surface materials and sustainable land-use designs.

The pattern of urban spatial development is a critical factor in the interactions between urbanization, climate-related risks, and vulnerability. Most urban settlements exhibit lower density population further from the urban core (Seto et al. 2010; Leichenko and Solecki 2008). In cities with a large fringe and unplanned settlements however, this pattern can be reversed. In both cases, urban growth is experienced through horizontal expansion and sprawl (UN-ESA 2011; Hasse and Lathrop 2003). Elsewhere, especially in Asia, rapid urban population growth in the last decade has been marked increasingly by growth in vertical density high rise living, as well as sprawl. Higher density living can offer opportunities for resource conservation, but also challenges for planning and urban management such as creating high volume, drinking water supply systems.

Current global urbanization patterns continue a long-term trend of decentralization, with many large cities in developing and developed country contexts extending out into metropolitan regions (Seto et al. 2010; Leichenko and Solecki 2005) that can force a multiplication of foci for economic activity, industry, educational excellence, and places of

poverty. It is often problematic for these multiple centers to interact in planned ways that can benefit from scale economies, creating pressures for geographical, social, administrative and political fragmentation (Laquian 2011). Urban expansion has fostered extensive networks of critical infrastructure, which are frequently vulnerable to climate change (Solecki et al. 2012; Rosenzweig et al. 2011). For instance, New York City's dispersed infrastructure networks faces several climate-related risks (Zimmerman and Faris 2010). For example, the provision of water for cities rapidly growing and relative water scarce, like Beijing, Delhi and Phoenix is increasingly being stretched. This generates heightened vulnerability to changes in precipitation patterns associated with climate change.

The rate of urbanization (i.e. the level of population growth, urban spatial expansion, and redevelopment of existing urbanized areas) in any city or metropolitan region is critical to understanding the connection to climate risk and vulnerability. Urbanization is associated with changing dimensions of migration and materials flows both within, and in and out of cities (Grimm et al 2008). The level of increase and some case decrease of these conditions create a dynamic quality in cities. Rapidly changing cities have the challenge of managing this growth via housing and infrastructure development, while also attempting to simultaneously understand the relative impact of climate change. The conflation of local environmental change resulting from urbanization with climate change shifts make the identification and implementation of effective adaptation strategies more difficult. For example, water shortages in many developing-country cities are already a chronic concern which typically worsens as the population continues to grow (Muller 2007). Overlaying climate change-related reductions in supply or heightened uncertainties facing water managers with this existing instability creates the conditions for greater management and governance crises (Gober 2010, Milly et al. 2008).

8.3. Climate Change Variability and Impacts

This section focuses on how climate change impacts urban centers directly, with specific reference to urban biodiversity. Climate change is likely to lead to the increased occurrence of extreme weather events such as heavy rainfall, warm spells and heat events, drought, intense storm surges and sea-level rise (see Hunt and Watkiss 2011; Romero-Lankao and Dodman 2011; Rosenzweig et al. 2011 for reviews). Climate change is likely to accelerate ecological pressures, as well as interact with existing urban environmental stresses (Leichenko 2011, Wilbanks and Kates 2010), particularly those associated with urban

biodiversity. For example, New Orleans' geophysical vulnerability is shaped by its low-lying location, accelerating subsidence, rising sea levels, and heightened intensity or frequency of hurricanes due to climate change (Wilbanks and Kates 2010; Ernston et al. 2010).

Alternatively, cities in arid regions already struggle with water shortages. Climate change will likely further reduce water availability because of shifts in precipitation and/or evaporation paired with rising water demand (Gober 2010). Cities' ecological and overlapping pressures have particular regional dimensions, as discussed below, and responses will depend strongly upon the quality of governance and adaptive capacity. These connections will be important when understanding the many specific types of impacts discussed below:

8.3.1. Inland and Coastal Flooding

Heavy rainfall and storms surges would impact the urban areas through flooding which in turn could lead to the destruction of properties and public infrastructure, contamination of water sources, water logging, loss of business and livelihood options and increase in water borne diseases as noted in wide range of studies (Rosenzweig et al. 2010). Extensive studies have attempted to better model the frequency and condition of extreme precipitation events and associated flooding (e.g., Ranger et al. 2011; Onof and Arnbjerg-Nielsen 2009)).

Sea-level rise represents one of the primary, if not the primary, shift in vulnerability in urban areas that results from climate change, given the accelerating urban growth in coastal locations (McGranahan et al. 2007, Dossou and Glehouenou-Dossou 2007). Rising sea levels and the associated coastal and riverbank erosion or flooding with storm surge could all lead to widespread vulnerability of populations, property, coastal vegetation and ecosystems, and threats to commerce, business, and livelihoods (Hanson et al. 2011; Carbognin et al. 2010; Pavri et al. 2010). Structures constructed on in-filled soils in the lowlands of Lagos, Mumbai and Shanghai are more exposed to risks of flood hazards than similar structures built on consolidated materials (Adelekan 2010; Revi 2009) where many cities include sites that have both a riverine and coastal storm surge component to the flooding (Mehrotra et al. 2011).

8.3.2. Urban Heat and Cold

In general, climate change will bring increased annual and seasonal temperatures, and declines in mean monthly, seasonal, and annual temperatures, which will have important implications for ecosystem function in cities. Heat waves and warm spells could exacerbate

urban heat island effects, including increased air pollution (Campbell-Lendrum and Corvalán 2007) and heat-related health problems (Hajat, O'Connor, and Kosatsky 2010), increased salinity of shallow aquifers in drylands due increased evapo-transpiration and the spread to new areas of some diseases, including malaria. The probability will increase for long term and spatially extensive heat waves, such as the heat wave that occurred across continental Europe in 2003. Increased warming is predicted in a wide variety of cities including sub-tropical, semi-arid, and temperate sites (e.g., Thorsson et. al. 2011). Conversely, widespread reduction in cold waves will reduce heating demands (Mideksa and Kallbekken 2010). Occasional more intense cold waves, such as in Ireland in recent years, resulting from increased climate variation could also have intense localized impacts.

8.3.3. Geo-hydrological Hazards

Climate related hazard exposure will vary due to differences in the geomorphologic characteristics of the city (Luino and Castaldini 2010). Climate change will increase the risk and vulnerability of urban ecosystems to a range of geohydrological hazards including groundwater and aquifer quality reduction (e.g., Praskievicz and Chang 2009; Taylor and Stefan 2009) and subsidence, and increased salinity intrusion. Subsidence caused by groundwater extraction has led some land in cities like Shanghai to sink by a several meters or more, this is compounded when groundwater is saline (eroding structures) or rainfall increases in intensity and duration. While urban areas located in lowlands will have higher risk to flooding, urban centers located in hilly areas will be exposed to landslides.

Drought will lead to food insecurity, increase in fuelwood prices, water shortages, decline in ecosystem function, and an increase in water related diseases (e.g., Farley et al. 2011; Herrfahrtd-Pahle 2010; Vairavamoorthy et al. 2008). Averaging across all climate change scenarios, recent findings suggest that nearly 100 million more city-dwellers “will live under perennial shortage under climate change conditions than under current climate” (McDonald et al. 2011).

8.3.4. Air Pollution and Public Health

The burden of allergies and asthma will rise as existing urban air pollution will be exacerbated through climate change-related mechanisms (O'Neil et al. 2009a; Reid and Gamble 2009b, Kinney 2008). Increased temperatures will promote the production of secondary air pollutants such as ozone, NO_x and Sox. Climate change may affect the

distribution, quantity, and quality of pollen, as well as altering the timing and duration of pollen seasons; the burden of asthma and allergies also could rise as a result of interactions between heavier pollen loads and increased air pollution, or as climate change promotes more frequent wildfires (Shea et al. 2008). Furthermore, climate change may contribute to long-distance transport of pollen and pollutants or heavy precipitation events such as thunderstorms, which are often linked to asthma epidemics (D'Amato *et al.* 2011).

8.4. Key Vulnerabilities - Exposure and Sensitivity

The objective of this section is to assess the observed and forecasted direct impacts of climate change influence on the exposure and sensitivity, and resultant vulnerability of urban biodiversity along with city residents, infrastructure, and other urban systems. Climate change will have profound impacts on a broad spectrum of city functions, infrastructure, and services (Rosenzweig et al. 2011; UN Habitat 2011). It will exacerbate the stresses already placed on urban ecosystems, generally, and will be particularly difficult for ecosystems that exist within marginal or limited ecosystem niches, such as wetlands. The section examines the temporal and spatial scale and occurrence (i.e. chronic vs. acute) of the shifts in climate risk across cities and urbanizing sites in the next several decades.

Climate change will promote seasonal temperature and rainfall shifts. For example, it is expected that winter temperatures will become warmer and wetter than other average annual shifts overall. Conversely, future summer weather will be associated with more drought periods, punctuated by more frequent heavy downpours. These shifts will impact critical water quantity and quality conditions and promote changes in the inundation periods for urban wetland ecosystems which will present challenges for a wide range of wetland species, increased water stress, shifts in budding and flowering timing, and persistence of seasonal pests.

The interaction between climate change and ongoing existing environmental stresses leads to a range of synergies, challenges, and opportunities for adaptation with links that are complex and processes that are often highly uncertain (Ernstson et al. 2010). The origins of these pressures can occur both *in situ* and as well as through long-distance connections between cities and often rural locations, such as sites of resource production and extraction (Seto et al. 2012; Satterthwaite et al. 2010).

Urban systems will be impacted by cascading risks due to climate change (Hunt and Watkiss 2011). Climate stresses, particularly extreme events, will have effects across interconnected systems – within specific sectors and across multiple sectors (Gasper et al. 2011). The cascading effects of climate change can have direct economic as well as indirect economic impacts (Hallegatte et al. 2011, Ranger et al. 2011), and can extend from infrastructure and built environment sectors to other types of impacts, particularly on urban public health (Frumkin et al. 2008, Keim 2008).

For example, shift in urban system disturbance regimes (e.g., fire, wind, drought) are important mechanisms to introduce phase changes (e.g., sudden or abrupt changes in habitat condition and quality) and pest species (e.g., invasives/diseases/parasites) in cities. Invasive species, including both plant and animal species, could become more established with extended drought or other disturbances. Expansion or strengthening of disease pathogens could threaten locally important species such as predators of local insect pests which in turn could cascade to increased number of the specific pest species. Winter warming and absence of cold waves will benefit certain species of insect pests and diseases that are sensitive to prolonged periods of cold; other invasive species may be able to respond more readily to warmer winter and spring-time temperatures.

These shifts have implications for urban health policy, such as monitoring aeroallergens and other associated ecosystem components for climate related shifts (Beggs 2010). However, additional research is still needed to understand the complex links between weather and pollutants in the context of climate change (Harlan and Ruddell 2011).

8.4.1. Ecosystem Health

Climate shifts will impact the resources available to urban wildlife including insects, birds, and other larger animals by changing the quantity, quality, and timing of forage for animals. It also can adjust the speed of onset of emerging diseases and other pathogens and alien/invasive species (e.g. plants and animals) now entering the extended regions around cities. The shifts in forage and in species composition will result in changes in species competition and pest management regimes. Increased droughty conditions will have a significant impact on ecosystem health beyond the relative strength of the drought. Reduced stream flows affect aquatic habitats and may cause or exacerbate chemical water quality problems such as eutrophication of already stressed urban ecosystems.

The character of each urban ecosystem provides important insights into the health of specific sites. For example, it is well understood that habitat parcel size is an important component of a system's resiliency, vulnerability, and adaptive capacity. Typically, larger parcels have greater resilience to external stresses because they are more likely to have resources to respond to sudden or gradual shifts.

8.4.2. Urban Ecosystem Habitat

Habitat for native plants and animals can hold significant value for urban residents. Wildlife appreciation activities including birding, hiking, and fishing make substantial contributions to the well-being of city dwellers. Many cities have successfully profited from its ecosystem habitats and species through these and other recreational programs. It is important to recognize that it is difficult to isolate climate change signals from the other stressors facing the urban ecosystems. Furthermore, it is clear that some climate shifts will not affect ecosystem habitats more directly than others. For example, climate change will likely result in identifiable forest tree species shifts, such as the decline in one species to be replaced by another better suited to the likely warming and moisture limiting climate. While this shift could result in an important loss of forage for one or more animal species, the forest composition shift could have negligible impacts on a forest's net value for watershed protection and water quality. Locally endangered species are particularly susceptible to climate change-related habitat shifts because they are already limited in extent and overall resilience.

The consequences of climate change on freshwater wetlands can be equally difficult to define and quantify. While it is clear that freshwater wetlands do provide benefits with respect to water quality protection, they are often not tied to specific commercial industries except for highly-altered wetlands that function as agricultural sites within urbanized areas (e.g. rice fields). The seasonal or extended drying of wetlands resulting from climate change will result in a decline in their capacity for water quality protection, thereby increasing water pollution in surface and ground waters and in nearby bays and estuaries. Breeding site effectiveness will be impacted by shifts in disturbance patterns emerging from more intense and frequent extreme climate events. For example, a loss of urban wetland habitat due to sea level rise and accompanying higher storm surge will be coupled with the fact that in urban contexts wetlands are typically unable to retreat inland because of shore bulkheading and intense coastal development. Wetland decline and loss might also mean a reduction in amenity value

and recreational visits for urban residents. Coastal wetlands and shore locations such as beaches with passive and active recreation sites are often intensively used by urban residents.

8.4.3 Urban Green Economy

A wide variety of ecosystem services and green infrastructure will be impacted by climate change. Climate change will alter ecosystem functions such as temperature and precipitation regimes, evaporation, humidity, soil moisture levels, vegetation growth rates (and allergen levels), water tables and aquifer levels, and air quality. These can influence the effectiveness of pervious surfaces used in storm water management, heat green/white/blue roofs used for urban heat island mitigation, coastal marshes such as flood protection, food and urban agriculture and overall biomass production, shifts in disease vectors (e.g., seasonality and intensity of mosquitoes), and decline in air quality because of increase in secondary air pollutants. In the case of Mombasa, for example, the city will likely experience more variable rainfall as a result of climate change, making initiating and expanding green infrastructure more difficult (Kithiia and Lyth 2011). Street trees in British cities will be increasingly prone to heat stress and to attacks by pests, including non-native pathogens and pests that could survive for the first time under warmer or wetter conditions (Tubby and Webber 2010).

Some ecosystem health impacts will be intensely local in their extent. Decline and increased stress on urban forest patches represent an excellent example of a significant local impact.

These parcels could include a small grove of trees or small forest stand in a park which are quite valuable to densely-settled locations as habitat or amenity resources but represent limited ecological value to the region or country in which the city is located. Loss of tree cover, habitat value, recreational value, and urban heat island mitigation value could have significant acre-by-acre costs to urban communities.

Box 1. Environmental and ecosystem service initiatives in New York City

Since 2010, New York City has developed a series of initiatives to promote ecosystem services within its green infrastructure. For example, local waters which have been increasingly viable as marine habitat as a result of federal water pollution control legislation have been analyzed as bivalve (e.g. oysters) spawning grounds. Within New York City's sustainability plan (PlaNYC 2030), bivalve habitat promotion is seen as an opportunity to further enhance local water quality protection. In general the

urban coastal zone, particularly including estuarine, bay, and beach environments, is often associated with the highest per unit area ecosystem service values. The nearly-complete linear Hudson River Park along the southwestern margin of Manhattan involves considerable recreated biodiversity in natural areas, green space, pathways, sports facilities and water access forming an intensively-used recreational area that includes fishing in the rehabilitated marine habitat. Interest also has increased in undertaking a major ecological restoration of Jamaica Bay, an extensive yet severely degraded wetland ecosystem (~3600 ha) adjacent to Kennedy International Airport. The driving force for the restoration effort is the increased provision of ecosystem services, particularly water quality protection, storm water management, promotion of native fisheries, and open space recreation. Other natural systems increasingly utilized in urban green economies include solar radiation and wind for electric power generation. Again in New York City, a comprehensive web-based solar map of the more than one million roof surfaces in the New York was recently released (<http://nycsolarmap.com/>). The objective was to provide information for property owners to take advantage of previously untapped electricity generating capacity.

8.5. Urban Wetlands and Climate Change

An important global scale, climate-related risk and key vulnerability to urban ecosystem health are the loss of freshwater and coastal wetlands. Fresh water wetlands are especially susceptible to shifts in seasonal water flows and must also compete for water resources during times of stress. A drought can have significant impacts on the hydrology of fresh water wetlands – increased frequency of drought could lead to a phase change or tipping shifts (e.g., non-linear changes in ecosystem function and properties that could lead to dramatic and potentially sudden transitions in ecosystem health) in wetland ecosystems leading to a loss and significant degradation of the system.

Sea level rise will cause shifts in flooding potential on the urban coastal wetlands and beach zones, which will alter the habitat quality of these locations at rates significantly above natural baseline conditions. The amount of sea level rise could have potential large-scale impacts on the areal extent and ecosystem health of the urban coastal wetlands, including permanent inundation, accelerated inland wetland migration (i.e., if the wetlands are not blocked by bulkheads or similar structures), and shifts in salinity gradients.

The loss and degradation of urban coastal wetland ecosystem will be likely the most significant single economic consequence of climate change on urban ecosystem health. The decline of coastal wetland ecosystem will result in primary and secondary impacts. Water quality decline in coastal wetlands will result in lower productivity among fisheries. Loss of estuarine wetlands will be associated with a decline in the overall function of these areas for absorption of pollutants and nutrient removal from river water.

Loss of coastal and inland wetlands to inundation, increased flooding, and sea level rise risk threaten critical habitats in urban areas (Ehrenfeld 2008). Plants and animals at the margins have the most limited adaptive capacity and could be most negatively impacted. Upland fringes of coastal wetlands could be susceptible to storm surge which are present in the upper reaches of coastal bays and extended estuarine environments. Interior fresh water wetlands could be susceptible to extended droughts associated with groundwater declines.

In New York City and much of the extended urbanized areas of the U.S. Mid Atlantic Coastal region (Figure 1), remnant coastal wetlands will be lost to sea-level rise because the wetlands will not be able to migrate inland due to bulkheading and intensive coastal development (Rosenzweig et al. 2012). Recreational sites such as parks and playgrounds also will be affected. In New York, recreational sites are defined as critical infrastructure and often located in low elevation areas subject to storm surge flooding (Rosenzweig and Solecki 2010). Although climate change is likely to have significant impacts on traditional tourist destinations, little existing research has examined the effects upon urban tourism in particular (Gasper et al. 2011).

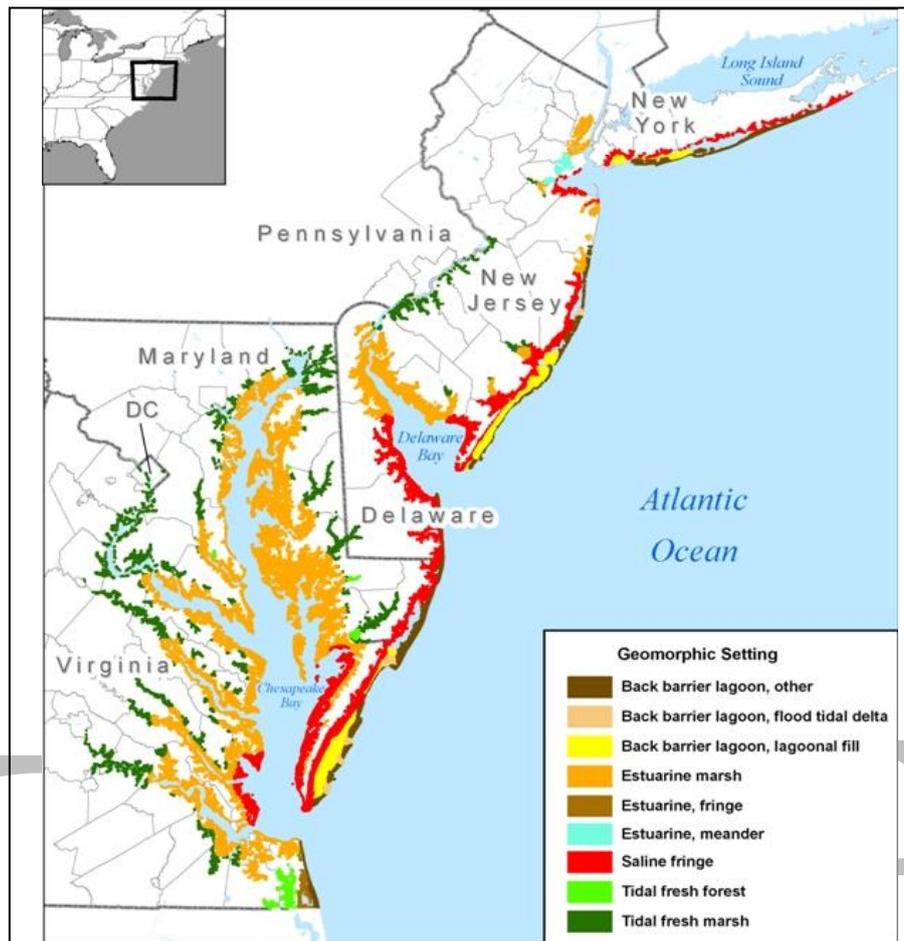


Figure 1. Coastal Wetlands in Urbanized Mid Atlantic Region in the United States; source: US EPA

8.6. Summary and Conclusions

Forthcoming.

8.7. References

Forthcoming.