Biodiversity, Biosphere Reserves, and the Big Apple

A Study of the New York Metropolitan Region

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ABSTRACT: The objectives of this article were to assess the dimensions of biodiversity–urban society interactions within the New York Metropolitan Region, a 31-county area with a population of 21.5 million, and to explore pathways to reconcile dysfunctional relationships between these two ever-entwined systems. The article builds on the premise that urban biodiversity exists at a crucial nexus of ecological and societal interactions, linking local, regional, and global scales, and that urban ecologies are projected to become even more dynamic in the future, particularly as a result of global climate change. The pathway proposed to reconcile the biodiversity–urban society relationships is the incorporation of biosphere reserve strategies into regional environmental planning efforts focused on the New York/New Jersey Harbor/Estuary specifically and on the greater New York Metropolitan Region in general. The concepts of the "ecological footprint" and vulnerability to global environmental change are used to analyze the current interactions between biodiversity and urban society, and to evaluate the efficacy of adopting biosphere reserve strategies in the region. New York has long been at the forefront of American environmentalism and landscape planning. Coupled with this history is a still small but growing interest in regional environmental planning efforts (e.g., the U.S. EPA Harbor Estuary Program) and green infrastructure (e.g., the 2002 Humane Metropolis Conference organized by the Ecological Cities Project). The research presented here aims to contribute to these nascent activities. As a megacity, New York may serve as a model for other major cities of the world.

KEYWORDS: urban biodiversity; biosphere reserve; New York Metropolitan Region; environmental change; ecological footprint

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> On this river there is great traffick in the skins of beavers, otters, foxes, bears, minks, wild cats, and the like. The land is excellent and agreeable, full of noble forest trees and grape vines, and nothing is wanting but the labor and industry of man to render it one of the finest and most fruitful lands in that part of the world … "—Johan de Laet, *Nieuwe Werldt ofte Beschrijvinghe van West-Indien* (New World, or Description of West-India) Leyden, 1625. Observation of New York Harbor

Human impacts on native biodiversity[a] throughout the globe have been profound. Urban biodiversity exists at a crucial nexus of ecological and societal interactions, linking local, regional, and global scales. It is becoming increasingly important to understand the impact of urbanization on the environment and how these kinds of impacts affect regional and global sustainability. Coastal wetlands, for example, in urbanized areas simultaneously provide sites for water runoff filtration, spawning ground for regional fisheries, and stopover points for migrating birds.

Although more traditional notions hold that the environments of cities are static and that once intensive development has taken place (e.g., urbanization), ecological functions and properties disappear, continual change in both the natural and the built environments characterizes even the most urbanized sites.[1–3] Urban ecologies are projected to become even more dynamic in the future, particularly as a result of global climate change. By the end of this century, global climate-related increases in sea level could be up to four times greater than the current rate of increase occurring naturally in the New York City region.[4]

Regional identity and structure underpin analysis of urban biodiversity in any location. As de Laet's description of the Hudson River's natural bounties illustrates, the Hudson River harbor estuary has long been at the core of the New York Metropolitan Region's structure and function (FIG. 1). The latter part of the 19th and early part of the 20th centuries brought accelerated resource demands as the region's population grew and industrialized, associated change in regional identity and structure, and decline of the core role that the harbor traditionally played, both literally and figuratively. Recent shifts in cultural values and redevelopment of coastal zones for financial services and residences have brought renewed interest in the harbor estuary region and calls for increased protection from groups and programs such as the NY/NJ Bay Keeper, Metropolitan Waterfront Alliance, and the Harbor Estuary Program.[5] As old port facilities and industries are replaced with commercial and residential developments, rejuvenated port infrastructure, and recreational sites, attention is again turning to the land–sea interface. As a result of these

[a]A common definition for biodiversity has evolved, although scholars and practitioners often stress varying elements of its definition. "All hereditarily based variation at all levels of organization, from the genes within a single local population or species, to the species composing all or part of a local community, and finally to the communities themselves that compose the living parts of the multifarious ecosystems of the world."[31] (p. 1).

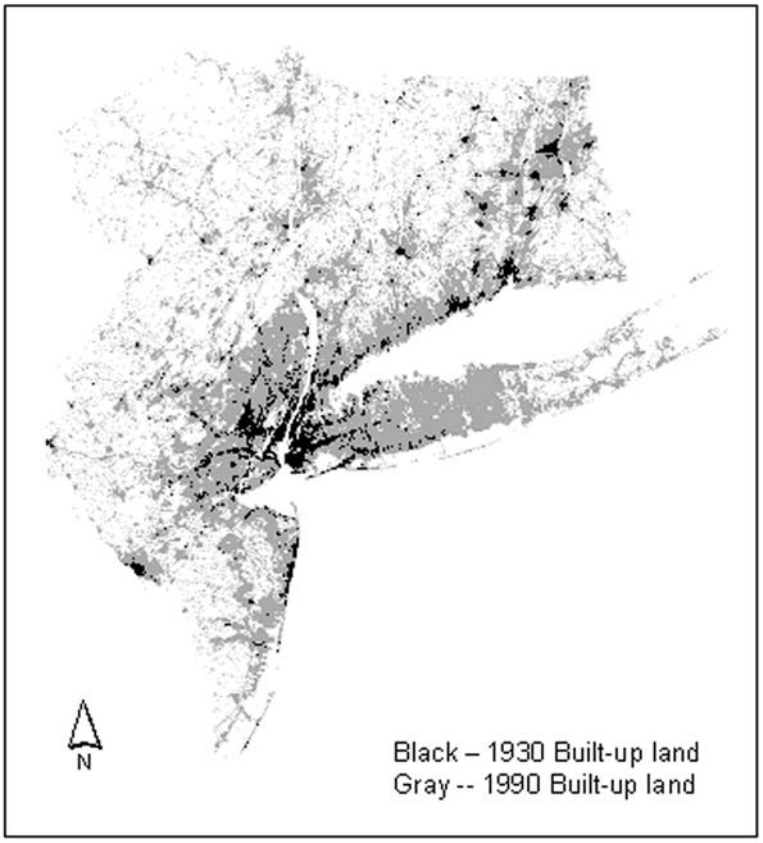

FIGURE 1. Urban and suburban land use in the New York Metropolitan Region–1990. (Source: Authors from USGS Urban Dynamics Program data.)

transformations, the New York Metropolitan Region as a whole, and, more particularly, its core area of the harbor estuary is an ideal place to study the dynamic relationships between urban ecology and culture, to evaluate the functions of biological and social diversity and to create a laboratory for sustainability planning.

The objectives of this article are to assess the dimensions of biodiversity–urban society interactions within the New York Metropolitan Region, a 31-county area with a population of 21.5 million, and to explore pathways to reconcile dysfunctional relationships between these two ever-entwined systems in a global megacity. Situated at the top of the urban hierarchy, megacities are massive in size, typically defined as having more than 10 million residents, and often play critical roles in the global economy.[6] The overall

goal of the article is to increase awareness and knowledge leading to better environmental resource management in urban areas. This is especially critical given UN estimates that, by the year 2025, five out of eight billion people will live in urban settlements, particularly in coastal locations.[7]

The pathway proposed to reconcile these relationships is the incorporation of biosphere reserve strategies into a regional environmental planning effort focused on the New York/New Jersey Harbor/Estuary specifically and on the greater New York Metropolitan Region in general. The concepts of the "ecological footprint" and vulnerability to global environmental change are used to analyze the current interactions between biodiversity and urban society and to evaluate the efficacy of adopting biosphere reserve strategies in the region.

As a megacity, New York may serve as a model for other major cities of the world. Although dense human settlements, by definition, put tremendous pressure on resources, individual resource demands in developed-country cities tend to be lower on a per capita basis than in adjoining lower-density suburban and rural areas. In developing countries, the resource demands of urban inhabitants are typically higher than in the surrounding rural areas. As developing countries, such as China, urbanize, it is useful to have models of developed-country cities that have been able to manage their resource demands and impacts on biodiversity in an equitable and sustainable fashion.

By embracing the urban biosphere reserve strategy, the New York Metropolitan Region once again could serve as a testing ground for new initiatives to meet the environmental challenges known collectively under the rubric of "the transition to sustainability."[8] The goal is for New York City and its environs to be known not only as the "Empire City," but also as the "Ecological City," a place where both biological and societal diversities flourish.

THE NEW YORK METROPOLITAN REGION

The generalized effects of cities on the environment are all abundantly and specifically present in the New York Metropolitan Region. The region is one of the most densely settled urban areas in the world, with a total population of roughly 21.5 million persons, of whom 8.0 million live in New York City.[9] Jurisdictionally, there are 31 counties and 1,600 cities, towns, and villages in the three states of New York, New Jersey, and Connecticut, besides the federal government and several regional organizations.[10] The largest financial trading market of the world defines the economic heart of the region.[11] The general economy is mostly based on service industries, which depend on modern, sophisticated means of communication and transportation. The gross regional product (GRP) is estimated at ~US$1 trillion. The region

maintains a versatile, high-volume transportation system by air and land (above and belowground roads and rails), as well as on the water. These and other essential infrastructure elements often are used to capacity.

With close to 1,500 miles (2,413.5 kilometers) of coastline, the region's development has been intimately connected to the ocean. Four of the five New York City boroughs are located on islands (Brooklyn, Manhattan, Queens, and Staten Island). Large waterways and water bodies, among them the Newark Bay/Hackensack Meadowlands, Hudson River, East River, Long Island Sound, Peconic Bay, Jamaica Bay, Arthur Kill, and the Raritan River estuary, cut deeply into the land area. The Hudson–Raritan River watershed encompasses about half of the area and includes some of the most densely settled parts of the region. Given its coastal location, much of the land area is at relatively low elevation; ~1% is below 3 meters (~10 ft) in elevation. This 1% encompasses some of the most heavily developed land and regionally important infrastructure, such as lower Manhattan, the three major airports (La Guardia, Kennedy, and Newark), and the Hackensack Meadowlands area. Besides the coastal plain, the Piedmont and Appalachian highlands physiographic regions are present in the west.

Although the region's ecology had been modified to a certain extent by Native Americans before the advent of European settlers, the scale of human modification has greatly increased since the Dutch founded the trading center in the 17th century. Some exurban areas, such as far eastern Long Island, northwestern New Jersey, and parts of Connecticut and New York State more distant from New York City still maintain extensive wildlife habitat. The native ecological function of the more densely settled part of the region is relatively low. However, the few remaining habitat sites there—for example, the Hackensack Meadowlands and the Great Swamp (both in New Jersey) and Jamaica Bay (in New York) and smaller-scale locations, such as in Newark Bay and the Kill Van Kull—provide critical stopping points for migratory bird species. By some estimates, these sites have witnessed significant increases in species-richness in the past several decades as some of the waters have become cleaner.[12]

Critical and vulnerable habitats in the region have been heavily degraded. Most of the region's prehistoric wetlands have been lost, and buffer areas around wetlands or rivers typically no longer exist.[13] In many areas, smaller rivers and streams have been filled, channelized, or placed into culverts. Surface water and groundwater supplies, particularly in the more heavily urbanized areas, have been compromised and typically exceed federal water pollution standards. There are more than 100,000 leaking underground fuel tanks, spill sites, or former industrial sites included on the federal government's register of known or potential toxic sites.[14] Many are located in lowland locations where coastal wetlands were used as landfill sites. There are 131 Superfund hazardous waste sites in the region that are undergoing varying levels of remediation.

TABLE 1. Energy and water consumption in the New York Metropolitan Region and developing countries of similar population

	New York Metro Region	Ghana	Iraq	Malaysia	Peru
Population	21,500,000	19,678,000	22,450,000	21,830,000	25,320,000
Energy consumption (quadrillion Btu)	7.50	0.11	1.09	1.86	0.56
Per capita energy consumption (million Btu)	348.84	5.50	47.40	79.80	21.80
Domestic water consumption (million m^3)[a]	2121.56	105.00	1280.00	1342.00	1260.00
Per capita water consumption (m^3)[a]	265.20	5.34	57.02	61.48	49.76

SOURCES: Energy Information Administration, U.S. Department of Energy, 2002; FAO Aquastat Online Database, 2000.
[a]Values are for New York City (population: 8,008,278).

New York's Ecological Footprint

Urban areas require more resources than their regions can provide and must import food, building materials, and fuel from elsewhere. One way of comparing resource use and land management is by calculating an area's *ecological footprint*, or what can be otherwise designated its *resource-shed*. The ecological footprint is the interactive relationship between an urban area and its hinterland (see Rees,[15] Folke *et al.*,[16] and *Ecological Economics*[17] for more information about the concept and its application). The large, relatively wealthy population of the New York Metropolitan Region consumes more goods and resources than many developing countries (TABLE 1). Estimates of per capita and total use of resources may be calculated for water, food, and energy.

The New York City Water Supply System serves as an excellent example of the character and shape of a local ecological footprint (FIG. 2). The system supplies 1,500 million gallons per day (MGD) to residential, commercial, and industrial users throughout the region and flows from upland reservoirs in the Catskills down through all parts of New York City. Water is collected from upland watersheds, held in storage reservoirs, and sent via a system of tunnels and aqueducts through balancing and distribution reservoirs to distribution mains in the city and other user areas. Water is collected and stored in three upland reservoir systems, the earliest of which began service in 1842. The total area of the watersheds is nearly 2,000 square miles. The most

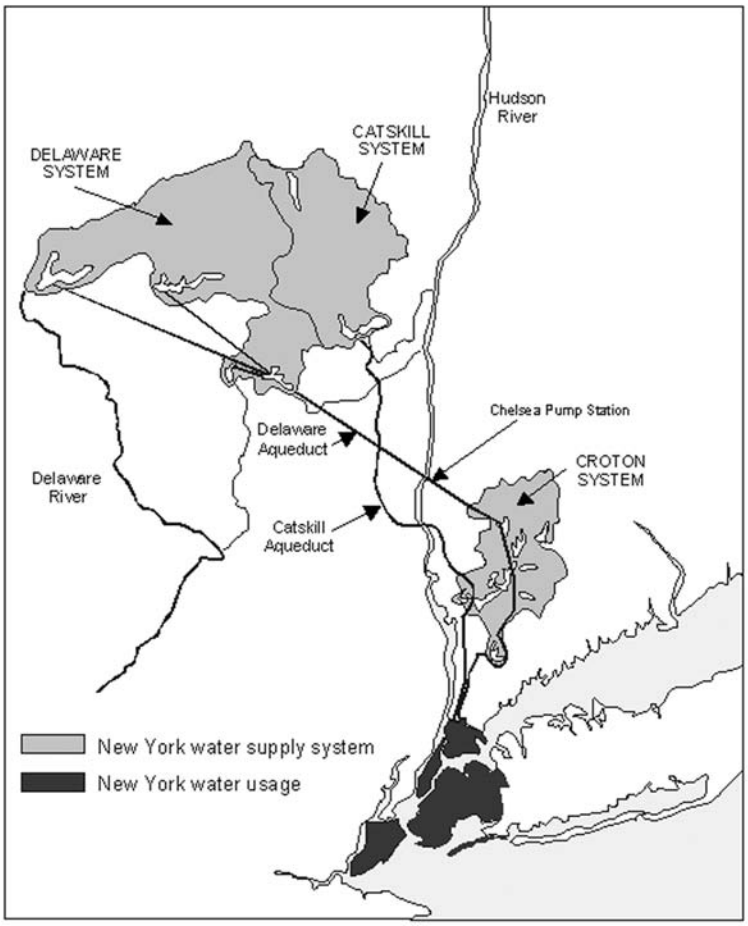

FIGURE 2. The New York City water supply system and water usage area. (Source: Major and Goldberg.[18])

pressing problem facing the system is the potential decline in water quality associated with increased suburbanization and nonpoint pollution around some of the upstate reservoirs. Rising water demand and long-term vulnerability to climate change–induced droughtiness and floods are other problems of increasing concern for decision makers.[18,19]

The New York Metropolitan Region also places demands on locales very distant from its borders and even its watershed. For example, the population's demand for food and energy extends throughout the nation and the globe. Almost all of the region's food must be imported, especially because remaining nearby farmland is continuously converted to suburban land uses. For one aspect of the ecological footprint of the region's food demand, we estimate

that the population consumes bread and pasta products from approximately 800,000 hectares of wheat. This is roughly equivalent to the total acreage of wheat grown in the state of Nebraska. The region's annual energy demand is equivalent to approximately 7.7% (7.5 quadrillion Btu) of the nation's total consumption. The region's demand then is comparable to the total of energy consumption of South Korea (7.35 quads) and slightly less than that of Brazil (8.51 quads).[20]

A major by-product of the United States' consumer society is a tremendous amount of waste. For the New York Metropolitan Region, some 2.5 billion gallons of treated effluent are put into the Hudson-Raritan Estuary every year.[21] Some locales in the region are among the most contaminated in the country. There are potentially hazardous levels of organopollutants (PCBs, PAHs), carcinogens, and heavy metals (i.e., cadmium, lead, mercury) floating freely in the water, trapped in sediments, and bioaccumulated in the tissues of marine organisms.

The New York City commercial and municipal sectors generate approximately 45,000 tons of waste per day (TABLE 2). Historically, much of the

TABLE 2. Disposal, recycling, and export of New York City waste

(a) New York City waste disposed and recycled in 2000 (tons/day)	
Waste managed by the NYC Department of Sanitation (municipal waste)	18,327
Disposed	11,926
Recycled[a]	6401
Waste managed by private companies	27,555
Total waste	45,882
(b) Percentage of municipal waste exported	
1997	0.0%
1998	14.9%
1999	24.2%
2000	48.4%
2002 (projected)	100.0%
(c) Municipal waste export locations and disposal methods: July 2001 to January 2002 (tons/day)	
Ohio landfill	1174
Pennsylvania landfill	8074
Hempstead and Peaksfield, NY, incinerated	258
New Jersey 15% landfill, 85% incinerated	1760
Virginia landfill	1631

SOURCE: New York City Independent Budget Office, 2001.
[a]As of 2002, plastic and glass recycling has been discontinued.

waste disposal in the region has taken place locally via either landfill or ocean dumping. Volumes, types of disposed materials, and disposal methods have changed over time. Increasingly, wastes are being exported out of the region, as dumping restrictions are put into place and waste facilities become more difficult to site. In recent decades, dozens of landfills in the region have closed. The famous Fresh Kills landfill on Staten Island, the last operating facility in New York City, closed early in 2001, although it was temporarily reopened to receive debris from the World Trade Center disaster. Today, trainloads of containers filled with residential and commercial waste are shipped hundreds of miles out of the region to states throughout the Middle Atlantic and the Midwest regions, particularly Pennsylvania, Ohio, and Virginia. As of 2002, plastic and glass recycling in New York City was suspended, increasing the amount of disposed and exported waste,[22] although the recycling program has now re-commenced.

Within-Region Resource-Use Differences

Although an ecological footprint may be estimated for the New York Metropolitan Region as a whole, there are significant demographic and spatial variations between urban and suburban residents in the level of per capita demand for resources (e.g., land and energy), other raw materials, waste production. Decentralization of the region and the rapid growth of far-flung suburban and exurban communities has been associated with increased resource demands, especially for transportation and living area (TABLE 3).

As the region grew, more land was converted to urban and suburban uses, including industrial, commercial, and residential areas. More than 30% of the total land area has been converted to such uses. There is currently a greater than 30-fold difference in density measures between the five boroughs of New York City and the other 26 counties in the region (TABLE 3). New York City had a population density in 2000 of 10,238 persons/km^2, whereas the rest of the region has a mean density of just 422 persons/km^2. Suburban counties have a far greater percentage of inhabitants who commute alone, and they use public transportation far less than do New York City dwellers. The result of sprawl has been a significant decrease in vegetative cover as well as fragmentation and destruction of animal habitats.

Suburbanization also brought greater demand for water resources, particularly for water for lawns, gardens, and swimming pools. Although only a relatively low percentage of the region's residents have swimming pools, most suburbanites have lawns and gardens onto which they apply high-quality drinking water to ensure vigorous growth. Overall, water demand among urban residents is much lower. A similar scenario is played out with respect to energy use. Urban areas, because of economies of scale, promote public transportation and walking, whereas suburban areas are built around the use of the automobile.

TABLE 3. Resource-use indicators in New York City and selected surrounding suburban counties

Location	New York City	Suffolk County, NY	Morris County, NJ	Rockland County, NY
Population	8,008,278	1,419,369	470,212	286,753
Persons per km^2	10,238	600.9	387.1	636
Number of commuters	3,192,070	670,406	239,839	132,302
Percentage of people who commute alone	24.9%	78.1%	81.2%	73.7%
Percentage of people who carpool	8.0%	10.1%	8.0%	11.0%
Percentage of people who use public transportation	52.8%	6.8%	4.2%	8.0%
Mean travel time (minutes)	40.0	31.8	29.4	32.6
Median number of rooms in one-family residence	3.8	6.3	6.6	6.3

SOURCE: U.S. Census, 2000.

Global Climate Change

Climate change may be viewed as the ultimate stress on a city where the dense population already puts tremendous demand on land and water resources.[23] Global climate models predict that New York in the 21st century will experience higher temperatures throughout the year and more heat waves in summer, rising seas, shorter recurrence periods for flooding associated with severe storms, and increased frequencies of drought and flooding.[24] These climate shifts, in turn, are likely to inundate coastal wetlands, threaten vital infrastructure and water supplies during extreme weather events, augment summertime energy demand, and directly and indirectly affect public health, all at the same time. Ecological diversity will be affected both directly and indirectly by these changes.

Climate change is already occurring in New York. Over the past century, average regional temperature has increased ~2°F, after the effects of the urban heat island have been removed. Precipitation levels in the region have increased slightly by an average of ~0.1 inch/decade over the same period. Climate change projections for New York City have been derived from extrapolations from the current trends and from global climate models (GCMs). The GCM-projected temperature changes are higher (4–10°F by the 2080s) than those projected by current trends (over 2°F in the 2080s), because the GCM scenarios account for increasing feedback from greenhouse gases that act as forcing mechanisms to warm the Earth's atmosphere (FIG. 3). Precipitation projections for the region do not agree in magnitude or direction, indicating hydrological uncertainty in the future.

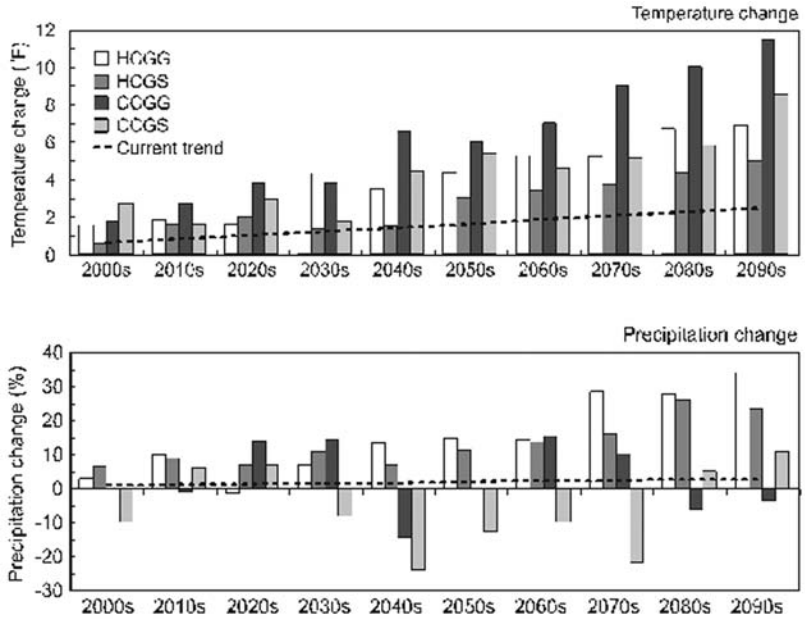

FIGURE 3. Decadal temperature and precipitation changes in the New York Metropolitan Region projected by the Hadley Centre (HC) and Canadian Centre (CC) climate change scenarios with greenhouse gases (GG) and with greenhouse gases and sulfate aerosols (GS), and by continuation of current trends. (Source: Rosenzweig and Solecki.[24])

Sea-level rise associated with global warming is the key vulnerability, resulting in widespread impacts on a region as closely linked to the ocean–land interface as New York. The current rate of sea-level increase is approximately 0.1 in/yr, with some regional variation.[25] Approximately half of this rate is associated with regional land subsidence linked to isostatic rebound of formerly glaciated land to the north; the other half is associated with the observed increase in global mean temperature rise (~1.2°F) over the period from 1900 to 2000.

The key threat of sea-level increase for the coastal city of New York is its effect on flood heights associated with storms. Heightened flood levels associated with future hurricanes and nor'easters (strong winter extratropical cyclonic storms) will cause the most significant damage. Given the projected rates of sea-level increase, Gornitz[26] and Gornitz and Couch[4] have estimated that, under a worst-case scenario, by 2090 a coastal storm event comparable to a 100-year flood could occur every 3–4 years. Much of the region's important infrastructure will be at increased risk to damage resulting from the augmented flood heights (FIG. 4).[26,27] The default public policy of placing

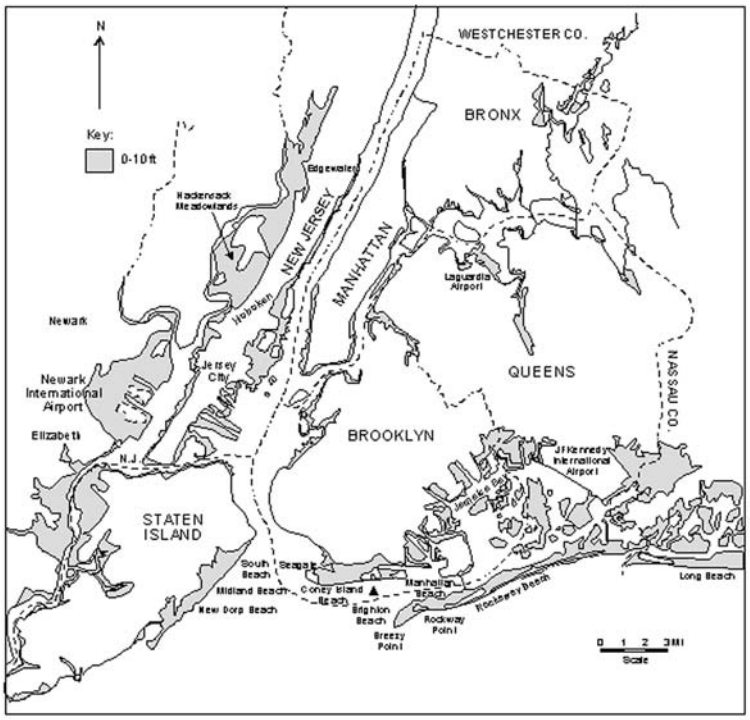

FIGURE 4. Flood risk zone, New York City and neighboring area. (Source: Gornitz.[26]).

necessary yet "locally unwanted land uses" on marginal lands, such as transportation infrastructure across and along the edges of wetlands, bays, and estuaries, has engendered risks of unintended consequences related to global climate change.

A different vulnerability is exhibited by the region's salt-marsh wetlands, important remaining habitat areas. Under natural conditions, wetlands respond to sea-level increase through accretion and in-migration; however, many of the wetlands in the New York Metropolitan Region can no longer respond in this way because of the reduction of sediment input and loss of upland migration sites resulting from extensive land development in the coastal zone. As the wetlands disappear with increased rise in sea level, their capacity to serve as habitat for local and migratory animals, particularly for waterfowl species, as protection of inland development from storm surges, and as natural filtration water purifiers will be diminished.

Severe wetland loss in the region's remnant coastal marshlands already has been recorded. Recent research indicates that salt-marsh islands in the Jamaica Bay Wildlife Refuge, part of the Gateway National Recreation Area, have decreased approximately 12% in size from 1959 to 1998.[28] Future scenarios

illustrate that rate of sea-level increase is likely to continue to exceed the accretion rate of the wetlands by the mid-part of this century, contributing to even more rapid disappearance of the wetlands.

PROPOSING THE NEW YORK BIOSPHERE RESERVE

As illustrated above, the 20th century brought dramatic increases in residents' resource demands in the New York Metropolitan Region and associated burdens on local and global biodiversity. Simultaneous economic and social transformations include increased overall wealth, suburbanization, and drastic shifts in the patterns and landscapes of consumption. Although the region became a site of global power and wealth, many within the region believe that its social, economic, and environmental fabric is threatened (e.g., see discussion in the Regional Plan Association 1996 report, *A Region at Risk*[14]). The dominant ecological and economic trends have made the region more vulnerable to perturbations such as extreme coastal storms, less sustainable as a result of increased per capita resource demands, and less equitable in terms of pollution exposure and quality of life.

To remedy these trends and promote more efficient and effective long-term ecologic and economic patterns of consumption and greater resilience of the region to future perturbations, we propose the development and implementation of a biosphere reserve management strategy. We contend that applying the biosphere reserve concept to the New York Metropolitan Region will result in direct and significant benefits for both the region's ecology and economy. The economic benefits of biosphere reserve planning will flow from the enhanced social importance and amenity values of greater and more nurtured open space and waterfront access, reduction in existing pollution and the costs of its control, and a reversal of the disharmonies and diseconomies of suburban sprawl.

Biosphere Reserves

As defined by the UNESCO Man and the Biosphere Programme, biosphere reserves are designed to serve three primary functions: to protect biodiversity, to encourage long-term observation of ecological trends, and to be laboratories for sustainability study and planning.[29]

A multitude of strategies can be used to achieve these programmatic goals. A common strategy has been the demarcation of *core*, *buffer*, and *transition* management zones. The *core* of the biosphere reserve is defined as the most important with respect to resource protection. These are sites where critical habitats and biodiversity resources are protected. The role of the *buffer* area is to protect the core, and the *transition* area serves as an intermediate zone between the buffer and the surrounding region.

Relatively few of the existing Biosphere Reserves are composed of three concentric rings of management areas. In most cases, the core is not a single site nor is it completely surrounded by a buffer zone. The core areas are often a set of parcels with the most exclusive zoning restrictions.

The UNESCO Man and the Biosphere Programme Biosphere Reserve designation does not come with any mandatory management constraints and is not associated with any loss of sovereignty of the host region or country to the UN or any other international body, counter to concerns occasionally voiced by local residents. The designation of an area as a Biosphere Reserve most often is largely a political act that adds to the legitimacy of environmental protection strategies already existing or proposed.

Zones and Functions

In the case of New York, a biosphere reserve could be constructed in two ways. The overall reserve region is the New York/New Jersey harbor estuary, including the New York Upper and Lower Bays, and adjacent coastal areas (e.g., Hackensack Meadowlands and Jamaica Bay), and the multiple adjoining resource-sheds. In the first approach, the New York/New Jersey harbor estuary area, as the site of the most significant ecological biodiversity in the region, is suggested as the *core* of the reserve (FIG. 5a). In the second approach, there is a distributed core encompassing all open spaces, parks, and wetlands across the New York Metropolitan Region (FIG. 5b). The designation of the latter as core emphasizes the need for rehabilitation, restoration, nurture, and appreciation of all remaining natural areas of the city. These two approaches to the core could be either alternative or simultaneous.

The *buffer* zone would include the watershed areas that surround either or both cores, including the watersheds of the Raritan River and Passaic River

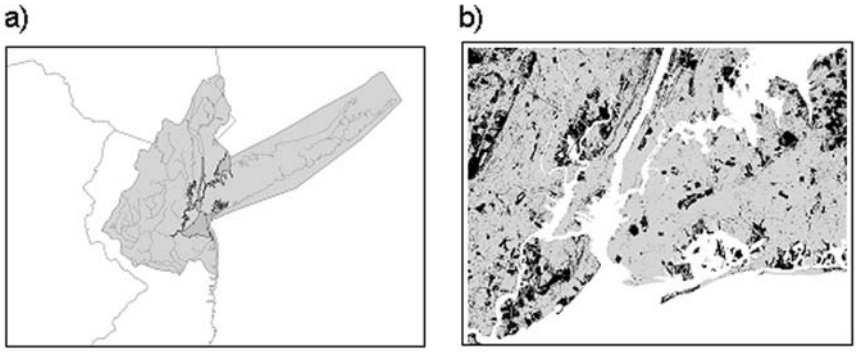

FIGURE 5. Biosphere reserve planning concept for the New York Metropolitan Region. (**a**) Core and buffer areas. (**b**) Parks and open space.

watersheds, the Hudson River watershed, and the highly degraded watershed region represented by southern Westchester County, New York City, and Nassau County on Long Island. These watersheds have the most direct ecological impact on the biodiversity of the core as a result of upstream land-use and habitat changes, water runoff, and the resulting pollution. The *transition* zone in the reserve would be represented by the resource-shed of the city, including all locations throughout the country and the globe that provide resources that serve the core and the buffer and/or receive its wastes. This transition zone is conceptualized as malleable, reflecting the changing spatial patterns of the region's resource demands. The distributed core creates transitions to neighborhoods, their vitalization, and reappreciation and emphasizes connections to social diversity.

This prototype urban biosphere reserve will function similarly to other reserves (i.e., by protecting regional biodiversity, becoming an observatory for long-term monitoring of ecological trends, and providing a laboratory for sustainability planning efforts). However, the role and significance of the core of the New York biosphere reserve represents a significant departure from traditional biosphere reserve planning. Traditionally, the principal objective of protecting the core is to preserve its critical biodiversity resources. Sustainability often is defined for the level of long-term resource protection that can take place. In the case of the New York biosphere reserve, the core is important both for ecological biodiversity and for societal and economic function. In this case, the core's local societal function, for its role as the focus for the region's activity and identity, is more important than its global ecological status. (The harbor estuary core of the New York biosphere reserve, while home to a wide array of species comparable to that of the Chesapeake and Delaware bays, is by no means a global biodiversity hot spot.)

Of heightened importance in the case of New York biosphere reserve is the sustainability function. Through the two different approaches to the core described above, the reserve will serve as an urban laboratory for sustainability experimentation. To augment and sustain the societal function of the core for the region as a whole, its ecological function needs to be sustained as well. And in turn, to sustain the ecological function of the core, the environmental inputs from the buffer areas (e.g., the surrounding watersheds) and other nearby transition-zone population centers (e.g., areas of western New Jersey and Long Island whose pollution inputs have an indirect impact on the core) need to be limited. In contrast, then, to most biosphere reserves where the transition and buffer areas serve the core in a largely unidirectional fashion, the New York biosphere reserve represents a much more interactive relationship among the three zones. In this case, the protection of the core preserves the ecological integrity of the areas and simultaneously enables it to fulfill its critical role as the social center of the region. This condition represents the true interdependence of the three zones that is the essence of the biosphere concept at its most effective.

SOCIAL AND ECONOMIC BENEFITS

In the case of the New York biosphere reserve, the promotion of the ecological function of the region will have at least three key local social and economic benefits: enhanced waterfront development, effective water-resource management (quality and quantity), and improved resilience to climate extremes and change.

Waterfront Development

Biosphere reserve management will help foster continued redevelopment of the waterfront zones, enhancing their economic amenity value. The Hackensack Meadowlands are an excellent example of the amenity value of a healthier ecosystem. In the 1960s, many residential and commercial developers shunned the Meadowlands because of its reputation as a polluted and severely ecologically degraded place. Since the late 1980s, the area has become increasing desirable real estate because of the environmental enhancement activities of the Hackensack Meadowlands Commission (closing of the garbage dumps and partial protection of the remaining wetland and natural areas) and the natural regenerative properties of the ecosystems themselves. Ecological areas, such as remnant wetlands, also can add value to adjacent brownfield sites that are undergoing redevelopment.

Water Resource Management

The biosphere reserve planning strategies applied to the New York Metropolitan Region will promote more efficient and effective water pollution–control activities. To promote the enhancement and protection of the harbor/estuary areas, the biosphere reserve strategies will encourage further controls of point and nonpoint sources of water pollution in upstream watershed areas. Biosphere reserve planning also will further promote strategies to encourage a reduction in suburban sprawl. This will be an integral part of the biosphere strategy because of the connection between sprawl and increased nonpoint source pollution into streams and rivers that eventually would flow into the harbor/estuary.

Although existing federal and state water pollution–control regulations have brought significant improvement to the water quality in the region, the biosphere reserve planning efforts will enable a system-wide review and analysis of synergistic impacts of water pollution on regional ecological conditions. By looking at the system as a whole, it could encourage greater amount of bi-state (between New Jersey and New York) cooperation in managing the harbor/estuary area. Each state has separately developed comprehensive environmental protection programs; however, there is little

coordination between the two beyond the limited amount that has been facilitated by the U.S. EPA New York/New Jersey Harbor Estuary Program.

Biosphere reserve planning will promote institutional adaptation and flexibility that allows for more integrated and adaptive decision making regarding current and future environmental management and biodiversity protection concerns. As has been shown in other sectors, when intergovernmental cooperation takes place, the management of resources becomes more effective (i.e., better able to respond to a wider spectrum of environmental concerns) and more efficient (i.e., less costly per unit of pollution reduction).

Climate Extremes and Change

Another economic advantage of biosphere reserve planning is that it will help lessen the vulnerability of the region to climate extremes and change. Vulnerability to flooding events will be lessened through reduction in impervious surfaces, leading to lower and less erosive runoff. Suburbanization causes a dramatic growth in impervious surfaces and inputs of stream sediments, both of which negatively affect the hydrologic regimen for increased flooding potential and to the degradation of downstream aquatic and wetland ecosystems. Impervious surfaces are associated with larger amounts of water being more quickly run off into stream and rivers. The resulting stream sediments are associated with a drastic decline in the stream and river channel depth. Biosphere reserve management can lead to decreases in flood-related property damage and destruction caused by these processes.

Biosphere reserve management also will help to protect coastal development and settlements from climate change–related sea-level increase and extreme event storm surges. The damage potential of an extreme coastal storm (a hurricane or large nor'easter) ranges into the tens of billions of dollars.[27] The promotion of an ecologically healthy core, particularly through the protection and restoration of coastal wetlands, will help promote locally important resilience to storm surges. During storm surges, coastal wetlands can become floodwater catchment areas, thereby protecting the surrounding built environment from inundation. As an example, remaining wetlands in the Hackensack Meadowlands currently serve as floodwater catchment areas for the surrounding urban and suburban lands.

CONCLUSIONS—BARRIERS AND BRIDGES

Regional planning efforts of any type, particularly that exemplified by biosphere reserve planning, have been inherently difficult to achieve in urban areas such as the New York Metropolitan Region. Gunderson *et al*.[30] discuss some of the barriers. Home rule and a splintered political landscape charac-

terize the region with its more than a thousand jurisdictions. In this setting, short-term political concerns tend to dominate, and long-term biodiversity and ecological issues often are not represented as having a wide-reaching societal impact. Policy responses to biodiversity protection also are hampered by the generally reactive nature of management organizations. Institutional action often is directed at immediate and obvious problems; issues that might emerge fully only after several decades are perceived as less pressing.

What is needed to move forward? Several initiatives will help to build the necessary foundation for the biosphere reserve strategy to be followed. These include education and outreach programs, methods for defining and entraining potential biodiversity impacts into planning decisions, and increased interagency communication and cooperation. Several organizations and programs are currently at work and achieving some success. Examples of these include the Regional Plan Association, Port Authority of NY/NJ, Metropolitan Transportation Authority, and federal agencies and programs such as EPA Region II and the New York/New Jersey Harbor Estuary Program.

Application of the biosphere reserve strategies described in this article will enable these and other regional decision makers to better understand the connections between biodiversity and urban societal demands, be more responsive to potential environmental changes on longer time horizons, and be more flexible in the face of increased climatic uncertainty. At the operational level, a New York biosphere reserve will provide an excellent pathway for integration of new environmental management proposals, such as wetland restoration programs and climate change adaptation strategies, into stakeholders' decision-making practices.

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