VII. Resource Objectives

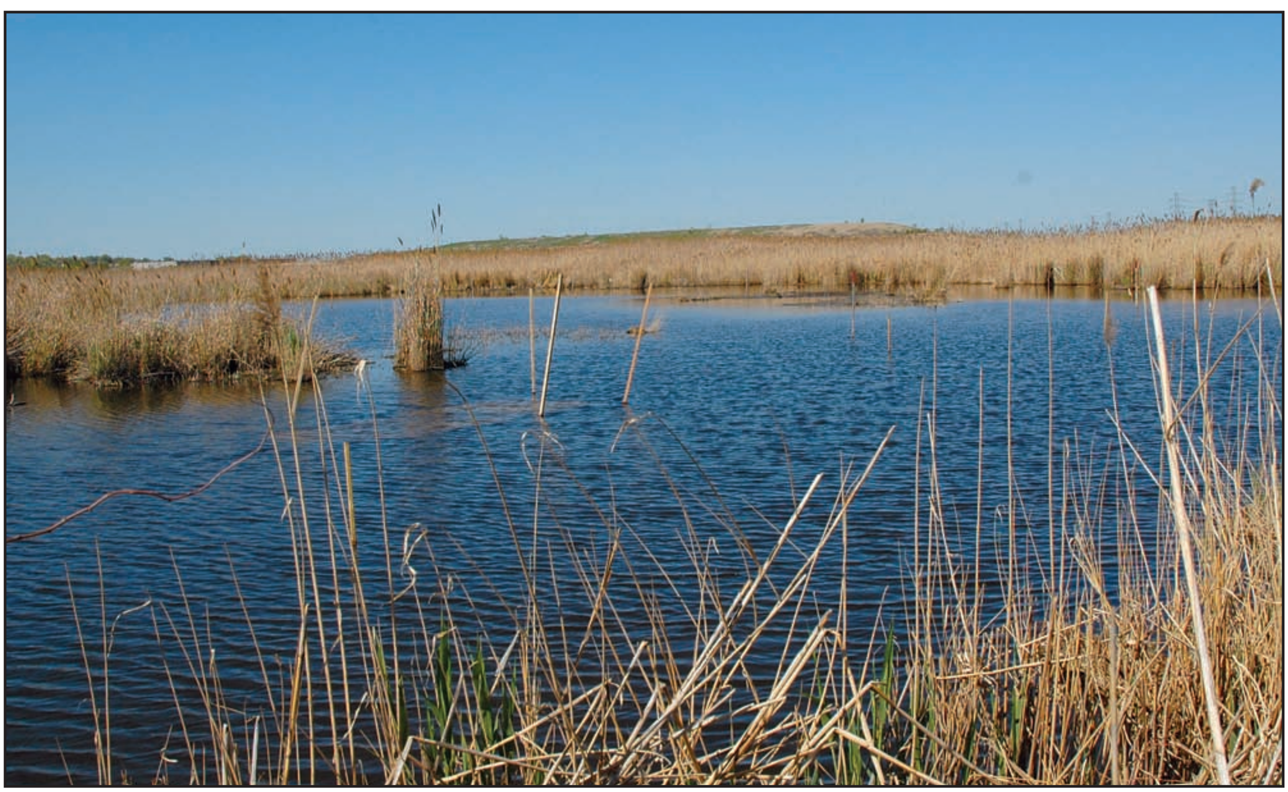
Great egret (*Ardea alba*).

VII. Resource Objectives

The Meadowlands' Sawmill Creek, pictured to the left, was established in 1975 as New Jersey's only urban Wildlife Management Area (WMA). Diking for mosquito control in the early 1900s promoted the spread of common reed, and led to further degradation of its marshes. In 1950, a northeaster destroyed the dikes and "restored" tidal flows to the Sawmill Creek marshes. The Sawmill Creek's extensive mudflats and cordgrass-marshes provide diverse habitats used by many animal species. However, the Sawmill Creek WMA also is fragmented by rail and road beds and bordered by the 1-E Landfill (shown in the figure background), which is being capped with dredged material from Newark Bay. Thus, the Sawmill Creek WMA not only provides inspiration for enhancing and restoring marshes, but also illustrates the diverse challenges to restoring the Meadowlands and safeguarding its fish and wildlife resources.

Landfills represent considerable challenges to remediating, enhancing, and restoring the Meadowlands and sustaining its biodiversity. On former wetlands, landfills presently provide extensive and contiguous yet degraded upland habitats for fish and wildlife. Some landfills are being remediated, with portions redeveloped to provide residential and commercial opportunities and extensive acreage transformed into golf courses. Golf courses often provide habitat for resident Canada geese and other, already over-abundant, nuisance species.

Alternatively, certain landfills (such as the 1-E pictured below in back of the Kearny Marsh) and other degraded industrial sites, properly remediated, may be restored to provide diverse upland "buffer" habitats that contribute important ecosystem functions as well as shelter, foraging and nesting habitats for many native species that now struggle to survive in the Meadowlands. The time has come to plan comprehensively and take corrective actions to reverse the pattern of destruction and ensure that the Meadowlands sustains populations of healthy fish and wildlife in the future.



VII. RESOURCE OBJECTIVES

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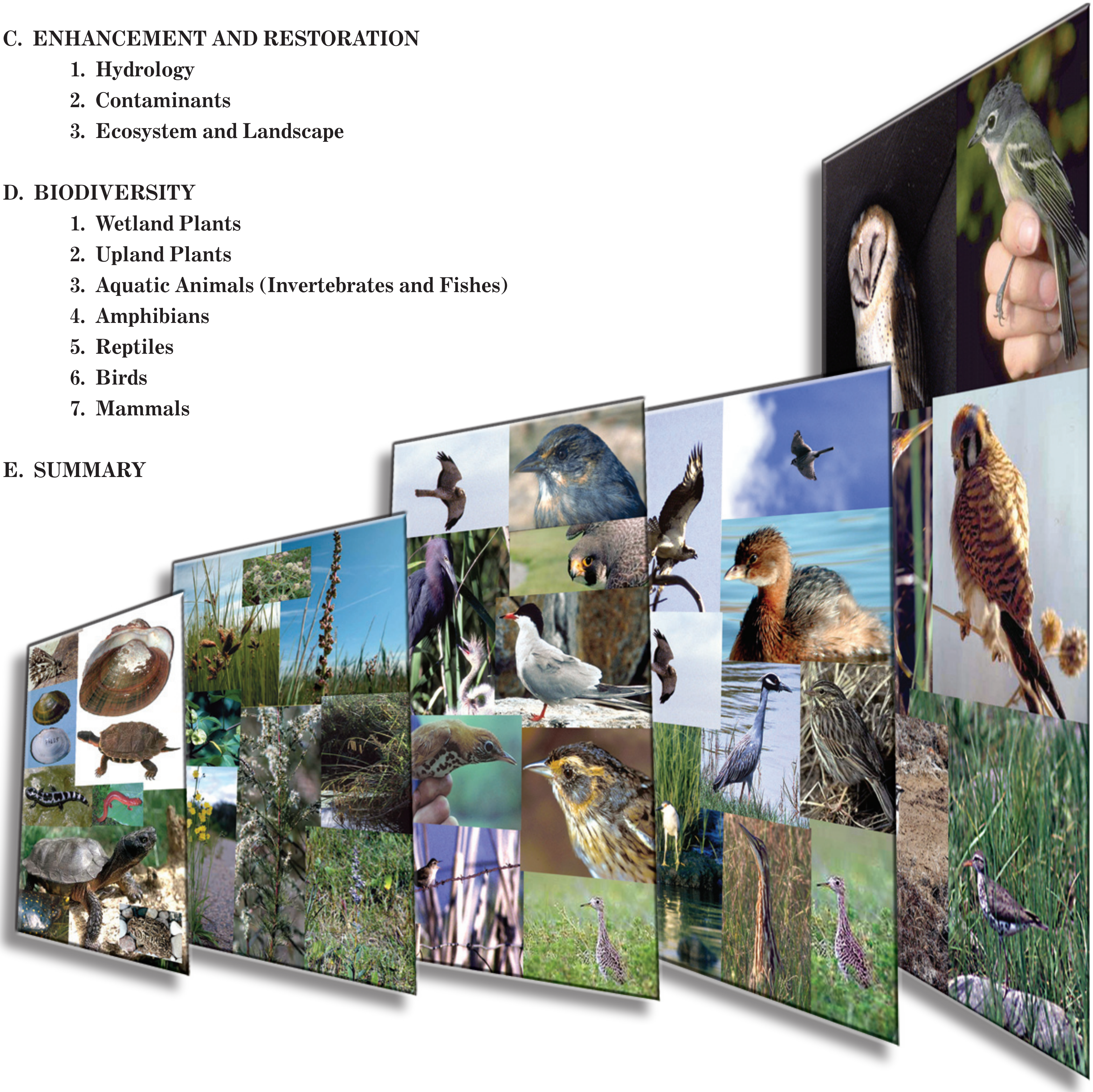
E. SUMMARY



VII. RESOURCE OBJECTIVES

A. ACQUISITION

1. Overview

Since the late 1990s, the NJMC has taken the lead role in acquiring wetlands within the HMD. Currently, the NJMC owns roughly 1,700 wetland acres, leases three other wetland sites totaling 361 acres, and manages an additional 1,600 acres of tidal wetlands, including the NJDFW-owned 878-acre Sawmill Creek Wildlife Management Area. In addition, in 2005 the NJMC supported the Meadowland Conservation Trust's acquisition of the 587-acre Empire Tract, the second largest wetland landholding in the HMD, in the Carlstadt-Moonachie wetlands. Altogether, these acquisitions represent vital steps for ensuring the long-term protection of nearly 3,400 acres of wetlands in the Meadowlands.

Current efforts to acquire additional open space within the HMD continue to be focused primarily on wetlands. The NJMC has identified wetland areas (totaling roughly 620 acres) within the HMD, owned by private individuals, corporations, and other public entities, as potentially suitable for public acquisition and preservation. Local governments (*e.g.*, Hudson County, Town of Secaucus) also are participating in collaborative efforts, such as the HEP's Habitat Work Group, to prioritize land acquisitions (Remaud, 2004). For example, Hudson County recently passed an open-space referendum to establish a trust fund generated through property taxes and has developed an Open Space Plan (Heyer, Gruel, and Associates, 2004) that has identified the County's open-space needs and priorities (*e.g.*, acquisition of riverfront greenway and brownfields, such as the PJP Landfill Superfund site, for public use). The NJMC has received a grant from the EPA to assess brownfield sites in the HMD. Acquisition of adjoining upland areas to provide wetland buffers and other open space is challenging and expensive but is necessary to protect the ecological integrity of the system and to provide habitats for non-wetland plant and animal associations in this densely populated urban area. The NJMC (2004d) has committed the 1-D and 1-A Landfills as restoration areas; however, most landfills in the HMD have been or appear targeted for re-development (*e.g.*, EnCap Golf, Inc.). Most acquisition of upland areas currently appears focused on waterfront parcels that would provide opportunities for public recreation (*e.g.*, landings, marinas).

Stakeholders in the region have taken initial steps to identify and acquire additional wetlands and adjoining uplands outside of the HMD yet within the HRW. The Service's National Wetlands Inventory is currently mapping and identifying wetlands within the HRW. The Meadowlands Conservation Trust is assembling a database of owners of waterfront parcels along the main stem of the Hackensack River. The Teaneck Creek Conservancy established a new 46-acre park in Bergen County that includes forested and other wetland areas, some of which are being restored with State funds (M. Arnold, pers. comm., 2004). The Borough of Oradell has acquired the former Hackensack Water Company site on Van Buskirk Island to protect the historical site and surrounding open space. The Bergen Save the Watershed Action Network (2005) established the Hackensack River Watershed Fund to acquire property in the upper HRW.

2. Objectives

The NJMC has taken and should continue a leadership role in the acquisition of wetlands and adjoining upland sites within the HMD. Federal and State agencies and other stakeholders have supported the NJMC's acquisition efforts indirectly (*e.g.*, identifying acquisition priorities [Remaud, 2004]), and may further assist the NJMC's future acquisition efforts. Wetland and riparian areas outside of the HMD but within the HRW remain under considerable threat of development; for example, development is being proposed on three riparian parcels along the Hackensack River, Lake Tappan, and Cherry Brook in River Vale Township. Thus, the Service recommends that stakeholders *further develop coordinating acquisition efforts outside the HMD throughout the watershed through the MCT*, which has the entire HRW designated as its operational area. In addition, the Service encourages stakeholders to investigate means to expand the funding mechanisms (*e.g.*, the Meadowlands license plate) that currently support the MCT. The acquisition of wetlands offers a community-based solution to the area's need for open space in addition to retaining wetland ecosystem functions in the watershed.

Acquisition of nearly all remaining wetlands in the HMD is a critical objective to restore the Meadowlands ecosystem and protect its fish and wildlife resources. The Service recommends *determining the priority of wetland and upland acquisitions* by size (large tracts preferred), proximity to other natural areas (connectivity to or closer preferred), and biological factors (*e.g.*, high biodiversity, and the presence of federal or State-listed, special-concern, and other "special interest" species preferred). Such spatial and biological factors affect a species' probability of colonization of and survival in different sites (*e.g.*, Hanski and Thomas, 1994). These priorities for site acquisition are also consistent with the Service's operating principles (Section I) to protect existing biodiversity. Urban ecosystems may differ unpredictably from less human-influenced systems in production, predation levels, and trophic dynamics (*e.g.*, Faeth *et al.*, 2005). Thus, acquiring more sites and increasing their connectivity may improve biodiversity in urban areas (Taylor *et al.*, 1993; Bueno *et al.*, 1995). The future outcomes and objectives of such acquisitions are subject to more detailed analyses of environmental contamination, hydrology, and restoration feasibility on a site-by-site basis.

Flood and storm water control projects have been integrated into large restoration programs elsewhere in the United States (*e.g.*, the Everglades, Lower Colorado River, Gulf Coast). The feasibility of integrating such projects into the remediation, enhancement, and restoration of the Meadowlands should be considered. Certain federal programs (*e.g.*, flood control, flood insurance, transportation projects, tax codes and policies, subsidized mortgage rates) and unsuccessful or partial mitigation of wetland impacts have contributed to wetland losses in northeastern New Jersey, including the Meadowlands. In recognition of the adverse impacts of federal programs on wetlands, the U.S. Department of the Interior (1994) recommended a long-term wetland acquisition plan as a primary aspect of a coordinated flood control program for northeastern New Jersey. At that time, no funds were committed to acquiring wetlands as part of the existing Passaic River Flood Control Program. Presently, the Corps is purchasing wetlands, riparian areas, and adjoining upland areas to preserve natural flood detention and retention storage areas in upper portions of the Passaic River watershed (U.S. Army Corps of Engineers, 2005a; 2005b; 2005c). Although not specific to flood control purposes, federal funding currently is committed to the NJMC to acquire wetlands within the HMD for their preservation.

Acquisition of additional wetlands throughout the HRW is justified not only for flood control (consistent with the 1994 DOI report) but also to improve ecosystem functions (*e.g.*, water filtration, nutrient cycling) and support fish and wildlife resources. The Service recommends that *stakeholders in the HRW coordinate activities to acquire substantial wetlands and adjoining areas to address and integrate enhancement, restoration, flood control, and open-space needs*.

Finally, the Service recommends *acquisition of riparian corridors and adjacent uplands and their preservation as open space to support fish and wildlife resources and provide passive recreational opportunities for the public*. Undeveloped riparian and upland sites are rare in the urban core and remain under increasing development pressure. Thus, the feasibility of remediating, enhancing, and restoring landfills and other contaminated industrialized sites should be investigated to reduce adverse impacts of contaminated areas on fish and wildlife resources and on humans. Depending upon the site-specific measures needed for their remediation, enhancement, and restoration, landfill and industrial sites may provide considerable opportunities to implement wildlife management and public use objectives. Because of the high cost of uplands in the urban/suburban area, Meadowlands stakeholders must develop a comprehensive plan that uses all available authorities and means to acquire corridors, buffers, and other upland areas. Acquisition of such areas is necessary for protecting the ecological integrity of the Meadowlands ecosystem and to provide habitats for upland plant and animal communities. Thoughtful public planning and implementation can result in a well-connected system of diverse wetlands, rivers, and ponds that are integrated with and buffered by public facilities, parks, and trails.

B. PROTECTION

1. Overview

Wetlands in the HMD are regulated by local laws (*e.g.*, NJMC's existing zoning regulations for all municipalities within the HMD), certain State laws (*e.g.*, Flood Hazard Control Act [N.J.S.A. 58A:16A-50 *et seq.*]), and federal laws (*e.g.*, CWA; see Appendix A). Uplands in the HMD generally have less protection, especially pursuant to federal regulations. Regulations at each level have limited capacity to protect wetlands; therefore, *all levels of governance have essential regulatory roles and a shared responsibility in protecting the Meadowlands and its fish and wildlife resources.*

Certain wetlands and adjoining uplands in the HMD owned by State agencies (*e.g.*, NJMC, NJDEP, and MCT) are managed pursuant to additional regulations (*e.g.*, Wildlife Management Area regulations, zoning regulations); therefore, not all publicly owned landholdings are similarly protected. For example, the NJMC (2004d) has proposed new zoning regulations in concert with its Master Plan for the HMD. The Master Plan sets aside extensive wetland (and to a lesser extent, upland) acreage for preservation and enhancement, and additional acreage for public recreational use. At this writing, the revised land-use plan and its zoning regulations have not been submitted to NOAA for determination of consistency with the Coastal Zone Management regulations (see Appendix A; K. Herrington, pers. comm., 2005). In the draft zoning regulations, wetlands and other open space remaining in the HMD are identified as wetlands, preservation areas, conservation areas, restoration areas, and enhancement areas; however, the meaning of different designations and the specific protections conveyed to those areas are unclear. In addition, radio towers and marinas, activities that have considerable potential to adversely impact fish and wildlife populations, are proposed as "special use exceptions" that could be allowed in certain areas. Any proposed changes to existing zoning and other regulations should be carefully evaluated for potential consequences on wetlands, restoration activities, and protection of fish and wildlife. Also, consistency should be ensured between the NJMC's 2004 Master Plan and Zoning Regulations in order to achieve long-term objectives. For example, instead of providing "special use exceptions" to allow communication towers in "preservation wetlands," zoning regulations should seek to reduce adverse impacts on fish and wildlife resources and allow only appropriate public uses of the public resources in those areas.

Miscommunication, inadequate coordination, and lack of consensus among federal and State agencies have adversely affected the protection of wetlands and fish and wildlife resources in the HMD for many years (*e.g.*, U.S. Department of the Interior, 1994). Recent activities (*e.g.*, filling of wetlands along Penhorn Creek in 2004, construction of guyed radio towers in wetlands along Berry's Creek in 2006) reflect a continuing lack of coordination between resource and regulatory agencies that must be addressed for restoration to move forward. Deed restrictions, conservation easements, and compensatory mitigation have not been applied in the HMD consistent with federal guidance in recent years. For example, deed restrictions on several wetland sites in the HMD have been transferred and proposed for transfer to other wetlands to accommodate proposed (non-water-dependent) projects. In addition, some mitigation banking provisions in the HMD are inconsistent with mitigation banking recommendations of the National Research Council (2001). Thus, additional coordination may be needed by federal and State agencies to bring mitigation wetlands and banks into compliance with federal and State policy guidelines and to prevent future losses of wetlands in the Meadowlands.

The NJMC executed an agreement with the NJDFW in 2004 to develop a HMD-wide conservation plan that will follow the format of the statewide Wildlife Action Plan (formerly the Comprehensive Wildlife Conservation Strategy). This State plan will identify and map those wildlife areas in the Meadowlands that warrant the greatest conservation efforts, and lead to establishment of an action plan, monitoring, and periodic review. The State plan will also evaluate and facilitate development of appropriate public access. This plan is being developed in cooperation with Ducks Unlimited, Inc., the New Jersey Audubon Society, and other stakeholders. Among its key benefits, development and implementation of this State plan should improve protection and promote recovery of State-listed species.

2. Objectives

Recent wetland acquisitions by the NJMC are key steps in preventing the continuing loss of wetlands within the HMD. Currently, most wetlands in the HMD are owned by the NJMC, NJDEP, and the MCT. Because the missions of these groups differ, wetlands under the various ownerships may be subject to different uses or potential threats. The Service recommends that the NJMC, NJDEP, and MCT collaborate on the formulation of any plans, policies, or regulations that may be necessary to *provide uniform, consistent protection of wetlands* under their respective stewardships. The Service also encourages these agencies and other stakeholders to consider the consolidation of wetland landholdings with the most appropriate State agency for long-term management and protection.

Long-term protection of wetlands under private and other ownership in the HMD remains uncertain due to continuing development and other pressures throughout the urban region. First, urbanization of the landscape (*e.g.*, housing, commercial and infrastructure development) far outpaced the growth of the human population in the NY-NJ Harbor area during the past three decades (Diamond and Noonan, 1996; Beach, 2002). In addition, wetlands in the HMD remain at risk because transportation needs in this urban region will continue to drive demand for improved transportation infrastructure (New Jersey Transportation Planning Authority, 2002). Thus, the Service recommends a coordinated effort by stakeholders to *explore diverse federal, State, and other mechanisms to provide long-term protection to the Meadowlands ecosystem*.

The Service recommends that stakeholders *consider formal establishment of an explicitly identified "preserve"* to protect the Meadowlands ecosystem. Long-term protection is a component of the Service's overall goal for the Meadowlands; federal and State agencies have considerable potential to provide long-term protection through several different authorities and administrative mechanisms that may be applicable to the Meadowlands. In response to a Congressional inquiry and appeals from local NGOs in 1999, the Service's Northeast Regional Land Acquisition Review Committee addressed the feasibility of establishing a Hackensack Meadowlands NWR. The Service decided that establishment of a Meadowlands NWR was not the best option due to contaminant concerns, other land-acquisition priorities, and budgetary issues. In addition, the central location of the Meadowlands in such a large urban and suburban area makes it difficult to prioritize needs of fish and wildlife consistent with NWR policy over the likely high demand for outdoor recreation and opportunities.

Other administrative mechanisms pursuant to federal authorities may strengthen the long-term protection of the Meadowlands. For example, the feasibility of incorporating the Meadowlands into, and managing it as a unit of, the Gateway National Recreation Area of the National Park Service could be explored. The National Park Service's mission is "to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations (National Park Service Organic Act, 16 U.S.C. 1)."

Other alternatives might include formal recognition of the Meadowlands as a marine sanctuary pursuant to the Marine Protection, Research and Sanctuaries Act (16 U.S.C. 1431 *et seq.*) or designation of this area as a Marine Protected Area (MPA) based on Executive Order 13158. A MPA is defined as "any marine area that has been reserved by federal, State, tribal, territorial, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." Different types of MPAs exist; workshops and training for resource managers and stakeholders in MPAs are supported by NOAA's Coastal Services Center. Designating the Meadowlands as a certain type of MPA, such as a National Estuarine Research Reserve (NERR), may provide additional federal funding for research and related activities. Currently, 26 estuarine areas have been designated as NERRs under the provisions of the national Coastal Zone Management Act (16 U.S.C. 1451 *et seq.*). The NERR system includes the Hudson River NERR in New York, the Jacques Cousteau NERR in New Jersey, and other imperiled ecosystems that do not fit strict definitions of *marine* or *estuarine* (*e.g.*, Old Woman Creek NERR on Lake Erie). Because the primary purpose of the NERR system is research, other legislative protections may be needed. Thus, establishment of the Meadowlands as a National Marine Sanctuary (NMS), another type of MPA, has potential to provide considerable long-term protection of the Meadowlands and its resources. A NMS is defined (15 CFR Part 922) as an area of the marine environment of special national significance due to its resource or human-use values, which is designated as such to ensure its conservation and management. Designation of the Meadowlands as a NMS would require NOAA to establish its own federal permitting process for activities in the Meadowlands, including an independent application and review of activities such as wetland filling that require other federal permits (16 U.S.C. 1435 *et seq.*). Designating the Meadowlands as a NMS would still allow fishing, hunting, other recreational activities, and potentially even commercial resource harvesting. The Service recommends that stakeholders carefully consider all available alternatives for protection pursuant to existing federal authorities.

The Service recommends considering State mechanisms to protect the Meadowlands, but cautions that such actions alone may affect (*i.e.*, restrict) federal opportunities and mechanisms for restoration or other assistance. Otherwise, application of certain State authorities, such as the designation of the Meadowlands as a State Park, may provide suitable, long-term protection. Protection through county and municipal governments would achieve localized (partial) but not comprehensive protection. The Service supports application of authorities or mechanisms that would provide *broad*, long-term protection for the Meadowlands ecosystem and its biodiversity.

The Service recommends *revisiting the interagency MIMAC agreement to improve coordination* (as discussed in Section VII.A.2 above) and to ensure consistency with recent guidance regarding the CWA and with other concerns (*e.g.*, monitoring requirements, long-term stewardship and management) regarding mitigation in the Meadowlands and nationally (as discussed in Section X; National Research Council, 2001). For example, the Service recommends that federal and State regulatory agencies and the MIMAC require upland buffers as a component of compensatory mitigation for projects adversely impacting wetlands in the HMD. The Corps has the authority to require vegetated buffers next to streams and other open waters in keeping with the CWA's goal to restore and maintain the chemical, physical and biological integrity of U.S. waters (National Mitigation Action Plan, 2004). Guidance regarding the assessment and incorporation of upland buffers as components of compensatory mitigation projects is currently available (*e.g.*, Corps *et al.*, 1995; U.S. Army Corps of Engineers, 2001; 2002b). Also, reinvasion by common reed elsewhere has led to recommendations that monitoring of mitigation sites be extended to at least 10 years (*e.g.*, Chesapeake Bay *Phragmites australis* Working Group, 2003); currently, monitoring of mitigation sites in the Meadowlands is typically required only for 5 years. Revisions to the MIMAC agreement to improve coordination, require vegetated buffers, and ensure long-term stewardship would assist federal and State agencies in preventing losses of wetlands and in improving the functioning of wetlands provided as compensatory mitigation. Finally, the MIMAC should investigate varied efforts to improve the functioning of mitigation wetlands and make mitigation projects more consistent with other, ongoing remediation and restoration activities in the HMD.

C. ENHANCEMENT AND RESTORATION

Enhancement and restoration both employ manipulations of physical, chemical, and biological attributes of the environment and differ primarily in the "historical" nature of the outcome achieved on the site. Enhancement does not involve a return to former functions or conditions, whereas restoration specifically seeks the recovery of historical functions and conditions though not necessarily functions or conditions that existed prior to any human disturbance. Estuaries are dynamic ecosystems with different landscape components (*e.g.*, open water, intertidal) that may undergo succession; the Meadowlands is known to have changed considerably over the past 10,000 years. However, without detailed knowledge of the entire history of all sites throughout the Meadowlands, it is difficult to determine whether habitat and other manipulations of a single site are best defined as enhancement or restoration.

To date, approximately 650 acres of wetlands at 10 sites have been or currently are being restored in the HMD (U.S. Army Corps of Engineers, 2004a). Most of these sites were restored as compensatory mitigation for federally permitted projects and have been acquired by the NJMC. To date, approximately 240 acres of wetlands remain under private ownership within the HMD that have been or are being restored as compensatory mitigation for impacts to other wetlands. The Corps' (2004a) MESIC report identifies nearly all other unrestored wetlands in the HMD as potential restoration sites. Although the vegetative cover of the restored sites has usually met regulatory requirements for success (> 85 percent coverage), comprehensive assessments of these sites (*e.g.*, Neckles *et al.*, 2002), including contaminant distributions and bioaccumulation, and the extent to which such sites sustain fish and wildlife populations, have not been conducted.

Except for sites within the HMD, efforts to restore wetlands throughout the HRW are in preliminary stages. The Service recognizes and supports the MCT's and other stakeholders' interests in pursuing restoration of Hackensack wetlands outside the HMD. For example, the Teaneck Creek Conservancy has received funding to restore a small palustrine wetland in the Overpeck Park area. The emphasis of this 46-acre forest restoration project is educational, recreational, and cultural, focusing on the history of the Lenape. The Service encourages major wetland or upland restoration projects outside of the HMD throughout the HRW. For example, several federally supported restoration projects are underway in upper portions of the Passaic River watershed (*e.g.*, Upper Rockaway River Ecosystem Restoration, U.S. Army Corps of Engineers, 2005b).

1. Hydrology

Enhancing and restoring the Meadowlands and protecting its fish and wildlife resources will require the development of a comprehensive program to assess, integrate, and coordinate efforts to address several complex hydrologic issues: (1) water flow, (2) system-wide improvements in water quality (including improved sewage treatment) to reduce nutrient and contaminant inputs, (3) flood control and storm water issues, and (4) SLR. Nearly all biological processes in estuaries are affected by the nature of freshwater inputs; therefore, a better understanding of hydrologic and ecosystem processes in the Meadowlands, including its capacity to process contaminant and nutrient inputs, is essential to improving water quality and promoting restoration. Enhancement and restoration will not be successful without a thorough assessment of the feasibility of improving hydrologic conditions throughout the ecosystem.

The NJDEP (1996) and DOI (1994) have recognized the vulnerability of the HRW to water supply and related flow problems. Water is currently diverted from the Passaic and Hudson Rivers (and some wells) into the Hackensack River above Oradell Dam (U.S. Geological Survey, 2003); therefore, water supply planning will likely require broad coordination by planners, resource managers, and interdisciplinary researchers focused on several adjoining watersheds (Pringle, 2000). Comprehensive water-supply planning that incorporates the needs of fish and wildlife has not yet been developed in the HRW as in other urban systems with similar environmental problems and high demand for water resources (*e.g.*, San Francisco Bay; CALFED Bay Delta Program, 2002).

Although a return to historic flows throughout the HRW does not appear feasible, *stakeholders should consider means to restore a more natural pattern of flows to the Hackensack River*, such as periodically requiring increased flows over the Oradell Dam. Additional monitoring and expanded flow analyses (*e.g.*, the USGS Water Information System, stream-flow maintenance assessments) in freshwater portions of the Hackensack, Pascack, and Passaic Rivers are recommended to determine any necessary flow modifications. Water conservation and re-use by all water users in the watershed, and especially major users (*e.g.*, Hudson Generating Station, which uses approximately 475 mgd for cooling purposes), may increase and restore natural flows, and merit greater consideration in regional water-supply planning.

Current and continued impairments to water quality throughout the HRW may limit and compromise successful ecosystem restoration. High concentrations of nutrients and trace elements affect autotrophic (*i.e.*, converting light and chemical energy to complex organic molecules) and heterotrophic (*i.e.*, generating energy from complex organic molecules) processes and biological communities in other degraded estuaries (*e.g.*, Sanders *et al.*, 1987; Wiegner *et al.*, 2003). Organic materials and nutrients from internal and external sources also have different fates in other degraded estuaries (Sobczak *et al.*, 2002). In addition, anthropogenic nutrient inputs may lead to hypoxic and anoxic conditions, which may alter the dominant trophic (predator-prey) relationships in degraded estuaries (*e.g.*, Breitburg *et al.*, 1997). Finally, nutrient inputs may shift the overall balance between production and consumption within estuaries (Kemp *et al.*, 1997). Additional research, including development of ecosystem models of key nutrients and contaminants, will be necessary to provide stakeholders an adequate understanding of the processes affecting water quality and the level of waste treatment required to protect living resources within the Meadowlands. Further research and performance standards are also needed to determine if programs of nutrient reduction are effective. Restoring the Meadowlands will require improvements in sewage treatment throughout the watershed.

Factors affecting water quantity, including flood control and storm water management, also may adversely affect restoration. If integrated and combined, such water resource projects may improve restoration success. For example, non-structural flood control and storm water management projects could provide additional riparian areas and storm water detention and retention areas around restoration sites, and contribute to improved water quality and the overall size of the natural area (*e.g.*, Pallone and Todd, 1997). Diversion of water from the Passaic watershed into the HRW can also affect flood control, storm water management, and restoration (including remediation) in both watersheds. Restoration partners should explore integrating restoration, flood control, and storm water projects to improve water quality and address other water supply issues throughout the Passaic and Hackensack watersheds. Information obtained by the USGS National Water Quality Assessment Program (NAWQA) has been used in managing, planning, and other decision-making (*e.g.*, stream-flow maintenance objectives) for freshwater portions of other coastal watersheds in New Jersey (*e.g.*, Ayers *et al.*, 2000) and is likely to be increasingly needed throughout the northeastern United States (*e.g.*, Pringle, 2000). The NAWQA Program should be expanded to include a number of monitoring stations throughout the Hackensack, Pascack, and Passaic watersheds to address flow and water quality issues in the upper portions of these connected watersheds.

Finally, *additional information on SLR and its modifiers is needed to assist long-term restoration and related planning for the Hackensack Meadowlands watershed, especially in the HMD.* Limited tide-gauge data available for the Hackensack Meadowlands suggest that SLR is occurring at rates comparable to the New York Harbor area (Hobble, pers. comm., 2004). However, additional information on sedimentation rates and relative SLR within the HMD, such as those provided by surface elevation tables (Cahoon and Lynch, 2005), is needed to determine relative SLR more precisely and to establish the vulnerability of marsh areas, especially those with different vegetation (*e.g.*, common reed, smooth cordgrass, saltmarsh hay). The interaction of SLR and other physical and biological factors will strongly affect the outcomes of restoration throughout the Meadowlands.

Scientific consensus regarding SLR has been slow to develop; therefore, policy makers and planners have not fully considered SLR's implications either to coastal communities or to ecosystems. Accommodating and planning for SLR is difficult in urban areas because human modifications to, and the value of, coastal property influence government priorities (Titus *et al.*, 1991; Boesch *et al.*, 2000). For example, highly developed areas will likely be protected from flooding at high costs (*e.g.*, with levees and pumps), whereas other less-developed or natural areas are more likely to be protected at lower costs (*e.g.*, by increased fill heights) or not protected at all (*i.e.*, allowing natural processes to proceed unimpeded). A gradual retreat of development from waterfront areas appears more likely in the Meadowlands than elsewhere in the NY-NJ Harbor. Such an approach would restore a more natural ecosystem with wetlands surrounded by adjoining riparian buffers. Sea level rise should be considered in long-term planning of storm-water storage, certain infrastructural facilities (*e.g.*, new sewage treatment plants), and hazardous waste sites (Flynn *et al.*, 1984; Sorensen *et al.*, 1984). Failure to plan for impacts of even modest SLR could affect the restoration of the Meadowlands by causing: (1) loss or conversion of wetlands, especially high marsh, to open water; (2) redistribution of contaminants, especially contaminants deposited in sub-tidal sediments, in certain erosional areas, or in heavily contaminated sites, such as landfills near wetlands; and (3) damage to sewage treatment plants or other utilities. Furthermore, lack of planning for SLR could result in substantial socioeconomic costs in the region (*e.g.*, storm-related damage to infrastructure, damage to coastal drainage and sewage treatment systems; Titus *et al.*, 1987).

2. Contaminants

Contaminants, both localized and widespread, present a formidable challenge to the restoration of the Meadowlands ecosystem. Despite the Service's substantial concerns about widespread contamination, Service objectives include the *enhancement and restoration not only of wetland sites within the HMD but also of nearby wetlands outside of the HMD* (*e.g.*, along Overpeck Creek). Virtually the entire Meadowlands ecosystem is contaminated by mercury, PCBs, pesticides, and dioxins from several Superfund NPL sites and other sources. Prudent restoration planning for the Meadowlands must include development of a comprehensive risk assessment regarding contaminants throughout the entire HMD and adjoining watersheds that can influence the health of this ecosystem (U.S. Fish and Wildlife Service, 2005b). Additionally, a state-of-the-art monitoring program of known and novel contaminants and their pathways must be instituted in a manner that addresses both risk and ecological health outcomes. Lastly, development and implementation of water quality criteria that protect wildlife from bioaccumulation of certain contaminants (*e.g.*, mercury, PCBs, and DDT; Buchanan *et al.*, 2001) must be integrated with the above activities.

The Service has developed a preliminary ranking of potential restoration sites based on available information and the degree of concern regarding contaminants (U.S. Fish and Wildlife Service, 2005b). Although progress has been made (*e.g.*, ENSR, International, 2004), insufficient information currently exists to assess and characterize contaminant risks in the Meadowlands for fish and wildlife. *Restoration of the Meadowlands cannot be adequately or fully achieved without a more complete knowledge of the distribution, availability, bioaccumulation and effects of contaminants from waste sites and other sources that are responsible for substantial health and ecological risk to fish, wildlife, and people*. On contaminated sites, restoration should not proceed until this assessment is complete. A recent risk assessment conducted in the Meadowlands (ENSR International, 2004) concluded that: (1) predaceous vertebrates exceed hazard quotients for certain contaminants (*e.g.*, mercury) substantially, and (2) "using site-specific factors [contaminant information] may lead to a significantly lesser degree of potential risk." Contaminants have considerable potential to adversely impact not only the successful restoration of the Meadowlands but also the sustainability of fish and wildlife resources within the region. The loadings and fates (pathways, availability, effects) of mercury originating from heavily contaminated sites in the Hackensack and Passaic Rivers have been identified as among the largest contaminant data gaps for the entire New York Harbor (de Cerreño *et al.*, 2002). Thus, development of a comprehensive risk assessment is critical to evaluating and implementing the most appropriate remediation, enhancement, and restoration alternatives.

In addition to contaminants presently impacting restoration, activities associated with restoration have the potential to exacerbate contamination of the Meadowlands ecosystem, that is, to increase contaminant availability and adversely affect fish and wildlife. For example, grading to achieve a desired elevation to re-establish tidal flow or connections may expose buried contaminants, which then become tidally suspended and redistributed. In addition, care must be taken that restoration does not result in population sinks or attractive nuisances, as has happened elsewhere in the United States. Examples include Lake Apopka, Florida, where a public restoration project caused deaths of hundreds to thousands of birds (U.S. Fish and Wildlife Service, 2001b) and the Channel Islands, California, where re-introduction of raptors was unsuccessful for more than 20 years (National Oceanic and Atmospheric Administration, 2005b). The effects of certain contaminants on a population may extend several generations beyond the generation originally exposed (*e.g.*, PCB effects on kestrels; Fernie *et al.*, 2001a; 2001b). Other research suggests that sink habitats have the potential to affect the long-term status of large populations (Howe *et al.*, 1991).

Removal of all historical contamination throughout the Meadowlands does not appear technically possible, even excluding any economic considerations; moreover, we do not know what percentage of contamination is possible to remove. A comprehensive risk assessment will, however, help identify the extent to which existing and future contaminants can and must be reduced, (*e.g.*, their existing problematic pathways to biota broken) and may possibly assist in restoring other areas within the HRE. For instance, criteria for removal of the invasive common reed from contaminated sites must be addressed during remediation and restoration risk assessments. Additionally, mercury and other contaminants may be broadly dispersed at substantial levels throughout a hydrologic sub-basin (*e.g.*, Berry's Creek and Canal) and beyond, which would justify restoring the entire sub-basin as well as the area to which this contamination has migrated. The incremental site-by-site approach of most current restoration projects in the HMD does not always provide this focus. Also, a determination of vertical sediment/soil contaminants distributions as well as the chemical forms of this distribution, when appropriate, is needed. The propensity of contaminants to bioaccumulate in aquatic and terrestrial species is critical to understanding exposure and effects. This understanding may provide justification for alternative approaches to restoration of specific sites, following remediation where necessary. Remediation should include evaluating the feasibility of contaminant isolation, such as capping sites or portions of sites, instead of contaminated materials being targeted for removal from the HMD.

Due to a large human population and extensive development, the Meadowlands ecosystem will continue to face challenges regarding contamination of waterways and wetlands from both current and future human activities. To address these challenges, restoration partners and natural resource managers must have timely access to precise information regarding anthropogenic inputs into the HRW. Thus, a comprehensive state-of-the-art program for monitoring water, sediment quality, and biotic exposure to contaminants must be developed. Monitoring should include nutrients, micronutrients, novel contaminants (*e.g.*, Kolpin *et al.*, 2002), and bioaccumulation of contaminants in selected taxa (*e.g.*, invertebrates [Penuto *et al.*, 2005], fishes [Kammen *et al.*, 2005; Weis, 2005], amphibians [Bank *et al.*, 2005], birds [Evers *et al.*, 2005]). In addition, coupling and transformation of nutrients and contaminants between the water column and sediment should be monitored, as bioavailability of those materials varies spatially and temporally with different sources (*e.g.*, Seitzinger *et al.*, 2002; Wiegner *et al.*, 2003).

Finally, federal and State agency stakeholders should work together to develop and implement water quality and related criteria (together with other performance measures) that guide restoration decisions and protect wildlife from bioaccumulation of certain contaminants, especially mercury, PCBs, and DDT. Wildlife water quality criteria previously developed for those contaminants (Buchanan *et al.*, 2001) have not been implemented in the State. These criteria and others, such as for dioxin-like compounds that occur throughout the HRE, are necessary to facilitate remediation, restoration or mitigation projects. An interagency and stakeholder (*i.e.*, public) consensus needs to be reached on what general conditions are acceptable for restoration, what level of contamination is acceptable, and the ramifications of allowing some contamination to linger.

The Service recognizes that examination of contaminants in the Meadowlands will almost always result in "some level of risk," especially from bioaccumulative contaminants such as mercury. Some small risk, especially to sensitive upper-trophic-level species, will likely be unavoidable during and after remediation projects as well as restoration projects. Some level of risk must be an accepted baseline following remediation and restoration in this urban estuary. This residual level of risk emphasizes the need to develop diverse performance measures to define and evaluate the success of remediation, enhancement, and restoration activities. This residual contamination also can be fully accounted for under the purview of CERCLA and other statutory authorities.

3. Ecosystem and Landscape

A major theme yet to be clearly defined is the broader landscape that will result from successful restoration of the Meadowlands. After decades of industrialization, how will the Meadowlands and the surrounding area be restored and protected? What will it look like, and how will it function? Restoring the entire Meadowlands to a tidal riverine ecosystem extensively forested with Atlantic white-cedar (*i.e.*, present from the 1400s to the late 1800s) is clearly unrealistic. One of the Service's primary objectives for the Meadowlands' restoration is establishing a more diverse landscape of mostly estuarine and other wetland communities of native plant, fish, and wildlife species; however, more specific objectives and features of that landscape have not been established. Restoration of the Meadowlands will likely rely primarily on increasing or re-establishing tidal flows over and within marshes, removing and replacing common reed with a few native estuarine and other wetland species, such as smooth cordgrass, bulrushes, and spike grass, depending on the location of the site within the estuary and the distances from tidal creeks and upland drainage. This approach has been widely used in many estuaries in other states for more than 20 years and in marshes in the Meadowlands for nearly 10 years. Studies of vegetation (*e.g.*, LaSalle *et al.*, 1991; Zedler, 1993, Warren *et al.*, 2002), invertebrate and fish communities (*e.g.*, Burdick *et al.*, 1997; Roman *et al.*, 2002), and birds (*e.g.*, Zedler and Callaway, 1999) indicate that recovery of certain species may take 20 years or longer. Such studies also suggest that establishing specific, hard and fast restoration targets may be unrealistic due to a host of physical and biological variables, but that wetlands with community structure and ecological functions similar to natural systems will develop given time and appropriate hydrology, substrate, and propagules (Warren *et al.*, 2002).

Ecosystem restoration began in the 1930s as an effort to repair systems damaged by agriculture; however, restoration of wetland ecosystems, especially degraded ones, is a more recent endeavor (Jordan *et al.*, 1987; Cairns, 1987). Also, changing degraded, dynamic, wetland ecosystems into more desired ecosystems is not a simple and straightforward process (Zedler, 2000; Peterson and Lipcius, 2003). Thus, research into fundamental and applied questions generated from restoration of previous sites in the Meadowlands (and elsewhere) and additional monitoring of ongoing restoration sites are continually needed to guide and improve restoration activities. For example, the invasive species common reed is re-invading older restoration sites in the

Meadowlands from which it was totally removed; thus, additional research is needed to determine why and how best to prevent re-invasion (*e.g.*, Bart and Hartman, 2000; 2002; 2003; Silliman and Bertness, 2003). Removal of common reed from some sites may be an ongoing activity that will be necessary on a continual or periodic basis in the future. A decrease in invasive species and an increase in indigenous species, particularly in the composition of the vegetational community, along with a rich and diverse native fauna and other indicators (*e.g.*, reproductive success), will provide a gauge of successful restoration. Also, restoration of certain sites can enhance specific processes and functions, some of which may favor different taxa (Havens *et al.*, 2002). For example, increasing subtidal habitats may benefit fishes whereas increasing intertidal vegetative (especially shrub) habitats may benefit birds.

Preliminary studies suggest that marsh restoration increases biodiversity within certain taxa (*e.g.*, birds, Siegel *et al.*, 2003), yet comprehensive assessments of restoring specific sites in the Meadowlands are lacking. Monitoring studies suggest that successful restoration generally increases vegetative cover by desired species (*e.g.*, Hartman, 2000; Louis Berger Group, Inc., 2000); however, restoration has not always resulted in vegetative communities consisting predominantly of planted and other typical species, due to secondary colonization by atypical volunteer (not planted) species such as salt marsh water hemp, marsh fleabane, marsh orach, and umbrella sedge (*e.g.*, Louis Berger Group, Inc., 2002a) or other, unknown reasons (Celebrano, 1995). Comprehensive assessment (*e.g.*, to include contaminants, hydrology, primary and secondary production) of different restoration sites in the Meadowlands has not been, but should be, undertaken. Such assessments may justify consideration of atypical restoration designs (*e.g.*, moats, caps, open water) on heavily contaminated sites. With EPA support, the NJMC also is evaluating use of wetlands restoration methods at Secaucus High School Marsh that have not been used previously in the Meadowlands. Monitoring and periodic assessment is also necessary for adaptive management of current restoration projects and design of future projects with changing conditions (*e.g.*, climate, sea level; French McCay and Rowe, 2003).

Finally, an increasing number of studies are identifying the unique features of urban ecosystems (*e.g.*, altered species composition and food webs, enhanced predation; Faeth *et al.*, 2005) and the potential to manage them (*e.g.*, Rudd *et al.*, 2002). For example, eliminating and replacing exotic vegetation throughout an urban landscape may have positive effects on the reproduction and survival of native bird species (Borgmann and Rodewald, 2004). For the purpose of this report, research and management efforts on urban habitats are secondary to restoration efforts in the Meadowlands and are not addressed in detail here. However, with increasing urbanization of the landscape in the HRW and the northeastern United States, there is growing recognition that such efforts will become increasingly important to the long-term protection of many species. For example, long-term transportation planning could address the fragmentation and hydrologic effects resulting from certain roadways (*e.g.*, I-95) in the Meadowlands. Thus, the Service recommends that stakeholders address urban ecology throughout the HRE in project and land-use planning. The consequences of human-induced landscape change must be better recognized by stakeholders in the Meadowlands and addressed collectively through long-range planning of major transportation and other urban redevelopment projects.

D. BIODIVERSITY

As previously discussed in Section III, biological communities of the Meadowlands ecosystem reflect considerable anthropogenic disturbances. In addition, among conspicuous groups of organisms that are comparatively well-studied (*e.g.*, plants, fishes), many species that were historically present within the Meadowlands have been extirpated. Restoring the Meadowlands to a former undisturbed condition (*e.g.*, a tidal riverine ecosystem extensively forested with Atlantic white-cedar, as was present from the 1400s to 1800s) and re-introducing all of its historical fish and wildlife resources are unrealistic. Nonetheless, the Service recommends addressing hydrological, chemical, and other conditions throughout the Meadowlands (and, in part, the surrounding watershed) as major components of a comprehensive remediation, enhancement, and restoration program. Such actions will increase the biodiversity of the Meadowlands and improve its capacity to sustain healthy native fish and wildlife.

1. Wetland Plants

For much of this millennium, the Meadowlands was a brackish to freshwater wetland ecosystem dominated by marshes with diverse vegetation (*e.g.*, threesquare bulrush, black rush, narrowleaf cattail, and cordgrasses) and interspersed with extensive forested stands of Atlantic white-cedar. Undisturbed, the Meadowlands supported extraordinary biodiversity and species richness. Though the idea of returning the Meadowlands to a forested wetland landscape is unrealistic given both natural and anthropogenic hydrologic alterations to the entire watershed, *establishment of a more diverse landscape of native wetland and upland species is essential to supporting the fish and wildlife resources of the Meadowlands and the region*. Thus, the Service's primary objectives for plant communities in the Meadowlands include: (1) increasing the biodiversity of native plant species in wetlands and adjoining uplands, and (2) reducing the vegetative cover by exotic and invasive species throughout the HMD and the entire watershed.

Increasing biodiversity of native species and reducing impacts of invasive and other exotic species are interdependent and are viewed as a "coarse-filter" approach (*sensu* Noss, 1987) for the long-term conservation of fish and wildlife in the region. Re-establishing and increasing the distribution, extent, and diversity of native plant species is critical to long-term support of fish and wildlife resources. For example, native plant pollinators may be adversely impacted by invasive plant species (Shepherd *et al.*, 2003). Heterogeneous (varied or patchy) landscapes of common reed may provide habitat for many birds and mammals (Marks *et al.*, 1994; Meyerson *et al.*, 2000); however, the form of common reed in the Meadowlands (Haplotype M), once established, grows into extensive homogeneous stands that do not provide high-quality habitats supporting diverse, native fish and wildlife communities. Juvenile fishes are less abundant in common reed-dominated marshes, possibly due to higher predation (*e.g.*, Able and Hagan, 2000; 2003), the different epiflora and epifauna living on common reed (Robertson and Weis, 2005), or marsh microtopography (Raichel *et al.*, 2003).

Recent studies of marsh restoration projects in New Jersey (Able *et al.*, 2005) have shown that secondary production of mummichogs (a common forage fish important to the diet of many marsh fishes and wading birds) is significantly lower in common reed marshes than in restored or natural cordgrass marshes. Secondary production may be considered a proxy for ecosystem functioning (*e.g.*, Peterson and Lipcius, 2003); in addition, mummichogs are the most abundant fish species in marshes in the Meadowlands. Lower secondary production of mummichogs potentially affects many other aspects of marsh ecology, especially for those species, such as piscivorous (*i.e.*, fish eating) wading birds, that directly interact with mummichog. The findings of these studies suggest that restoration projects replacing common reed with native cordgrasses are improving ecosystem functions. Similarity of the findings reported for mummichogs in the Meadowlands (*e.g.*, Raichel *et al.*, 2003) with those in Delaware Bay marshes (Able *et al.*, 2005) suggests that the current approach to marsh restoration (replacement of common reed with cordgrass) should continue. The Service recommends that secondary production of mummichogs in the Meadowlands be determined using methods similar to the Able *et al.* (2005) study to allow a direct comparison of results.

To date, restoration projects have increased vegetative diversity at most sites, though certain wetlands (*e.g.*, the MRI mitigation bank site; Louis Berger, 2004b) are now covered extensively by uncharacteristic species assemblages, and older (~10 years) restoration sites are being re-invaded by common reed. Research to date in the Meadowlands suggests that restored wetlands, including those with plant communities composed of atypical volunteer species, are being used by diverse wildlife (D. Smith, pers. comm., 2004); this observation is consistent with findings in marsh bird communities in other areas (*e.g.*, Chesapeake Bay; DeLuca *et al.*, 2004). The Service recommends that restoration of wetland sites therefore focus on eradication of common reed and its subsequent replacement with other vegetation, including replacement entirely by volunteer species due to the low success of plantings on some wetland sites (*e.g.*, MRI Mitigation Bank, Louis Berger Group, Inc., 2000). Additional research is needed into: (1) biocontrol of common reed, (2) factors affecting re-invasion of restoration sites by common reed, and (3) development of criteria to guide decision-making on removal of common reed from contaminated sites.

The vegetation of large areas in the upper portion of the HMD (*e.g.*, areas around Teterboro Woods, Losen Slote, Mehrhof Pond) is likely the most diverse within the Meadowlands, but has not been adequately surveyed in recent years and merits additional study. The Service's preliminary vegetative survey of the Teterboro Woods has identified more than 73 species in that area alone; other surveys report invasive, uncommon, and State-listed plant species in other wetland areas (Foote and Loveland, 1982; New Jersey Meadowlands Commission, 2004d; Kiviat and MacDonald, 2004). Thus, botanical surveys should be conducted throughout those and additional natural areas (*e.g.*, local parks) as soon as possible to guide future restoration and other land use activities at these oligohaline (low-salinity) and freshwater sites.

For example, NJDFW and the State's Natural Heritage Program should reassess the status of, and consider developing and implementing a management plan for State-listed and other rare native plant species in the Meadowlands. (Funded by the EPA, the NJMC is developing remote sensing techniques to determine vegetation types; such techniques may facilitate rapid identification of areas that have high vegetative diversity.) The NJDFW and Natural Heritage Program should periodically evaluate the need to assess adverse impacts on those plants from white-tailed deer (*Odocoileus virginianus*), which have returned to the Meadowlands. Deer populations are growing nationwide and are difficult to manage and control with traditional approaches (*e.g.*, hunting) for ecological, social, and political reasons (Brown *et al.*, 2000).

Management approaches suitable for nearby refuges or airports in southern New Jersey (*e.g.*, managed hunting, U.S. Fish and Wildlife Service, 1995; 2004d) may be applicable in the urban landscape of the HMD. White-tailed deer are reported to have eliminated more than 150 plant species from one urban park in Ohio (Peek and Stahl, 1997). Deer browsing also has pronounced direct and indirect effects on the distribution and abundance of other wildlife, including birds (*e.g.*, McShea and Rappole, 2000; Rooney and Waller, 2003; Côté *et al.*, 2004).

2. Upland Plants

Vegetated uplands are generally lacking because of extensive development in the Meadowlands; at present, the most extensive vegetated upland areas are closed landfills covered by common reed. Many disturbed upland areas such as roadsides and abandoned industrial sites in the HMD also are vegetated primarily by common reed and other invasive species that provide diminished support for fish and wildlife in comparison to areas vegetated with native species. Although such areas are far from natural in their origin, the closure, remediation, capping, and redevelopment of landfills potentially represents a considerable loss of vegetated open space, albeit primarily common reed. While the Service supports the closure and remediation of landfills, their replacement by golf courses further shrinks the total availability of upland habitats for native fish and wildlife. In addition, that "replacement" landscape may also support nuisance species (*e.g.*, resident Canada goose) that exacerbate problems for restoration of wetland sites throughout the HMD by feeding heavily on young vegetation at recently (within the past few years) restored marshes.

Remediation and restoration of landfills should focus on increasing native vegetation and biodiversity within the HRW. The NJMC (2004d) has committed to preserving the 1-A and 1-D Landfills as open space; the Service recommends that the NJMC commit to restoring extensive areas of additional landfills in the HMD with native upland vegetation, especially native grass and shrub species. Stakeholders should investigate and evaluate the vegetative communities most suitable for landfills in terms of their impacts on water quality and support for fish and wildlife and explore the use of tree species, as is being done on other landfills in the New York Harbor area (*e.g.*, Fresh Kills Landfill, Staten Island, New York; Handel *et al.*, 1997). Planting trees over landfill caps requires considerable volumes of clean fill; restoration partners should examine the scheduling of restoration and dredging projects to accommodate complementary needs (*i.e.*, the disposal and use of clean dredged materials).

In addition, the Service recommends that restoration partners and other Stakeholders increase the extent and quality (*i.e.*, native vegetation) of upland buffers throughout the HMD and the watershed. Upland buffers are increasingly recognized as critical to the functioning of wetlands, including their ability to support fish and wildlife resources. Buffers provide or enhance a number of ecosystem functions, including groundwater exchange, sediment removal and erosion control, moderation of storm water runoff, removal of nutrients and certain contaminants (*e.g.*, metals), moderation of water temperature, and maintenance of habitat and species diversity (Leavitt, 1998; Wenger, 1999; U.S. Army Corps of Engineers *et al.*, 2002). Disturbance of buffers surrounding high marsh habitat (especially the removal of woody vegetation) promotes the spread of common reed throughout New England marshes (Silliman and Bertness, 2003). Increasing the width of buffers decreased both non-point source loading of nutrients and invasion by exotic species in urban and suburban areas in New York's Hudson River Valley (Kleppel *et al.*, 2004). Increasing buffer width also increases the suitability of riparian areas as habitat for migratory birds (*e.g.*, Whitaker and Montevecchi, 1999).

3. Aquatic Animals (Invertebrates and Fishes)

In support of its overall goal for the Meadowlands, the Service's major objectives for aquatic animals in the Meadowlands are to: (1) increase native invertebrate and fish biodiversity, and (2) reduce the extent of disturbed and impaired aquatic communities, including those dominated by invasive and exotic species. These objectives are dependent on each other, and, to some extent, can be achieved only by improving water quality throughout the entire watershed. Rare species with specific habitat requirements (*e.g.*, gravel beds for spawning sturgeons) or other special requirements (*e.g.*, commensal species needed for freshwater mollusks) may require additional efforts to assist their recovery.

Many diverse phyla of invertebrates (*e.g.*, mollusks, arthropods) are critical components of aquatic ecosystems: they transfer and cycle nutrients, matter, and energy and link all other diverse components of wetland ecosystems (Mitsch and Gosselink, 1993). Invertebrate groups include some of the smallest, most abundant, yet least studied animals within the Meadowlands (Yuhas *et al.*, 2003; Robertson and Weis, 2005). Available information indicates that many of these invertebrates are adversely impacted by poor water quality and contaminants; for example, surveys of benthic macrofaunal and megafaunal invertebrates in the Meadowlands (*e.g.*, New Jersey Turnpike Authority, 1986; Kraus and Bragin, 1989) reported low species diversity with collections typically dominated by only a few common species (*e.g.*, sand shrimp [*Crangon septemspinosa*], grass shrimp [*Palaemonetes pugio*]). While the total abundance of benthic invertebrates in those collections was comparable to invertebrate abundance found in other portions of the HRE and other mid-Atlantic estuaries (Steimle and Caracciolo-Ward, 1989), invasive species (*e.g.*, the polychaete worm *Polydora ligni*, the bivalves *Macoma balthica* and *Congeria leucophaeta*) and pollution-tolerant species (*e.g.*, tubificid worms) frequently have dominated samples and contained few other species. Factors affecting the success of these species and their impacts on contaminant cycling and availability are not well-known.

Available information is scarce but indicates that the invertebrate communities in primarily freshwater portions of the Hackensack River also are imperiled by the extensive hydrologic alterations and poor water quality (especially turbidity) in upper portions of the watershed. The federally endangered dwarf wedge mussel (and perhaps commonly associated State-listed mollusks, the green floater [*Lasmigona subviridis*], yellow lampmussel [*Lampsilis cariosa*], and tidewater mucket [*Leptodea ochracea*]) apparently no longer occur in the HRW. The North American temperate freshwater fauna, especially mussels, appears to be losing species as rapidly as tropical forests (Ricciardi and Rasmussen, 1999). The diversion of water from the Passaic and the Hudson Rivers also increases the likelihood of invasive mollusks (*e.g.*, the zebra mussel) and other exotic species being introduced into freshwater portions of the upper Hackensack River above Oradell Dam. Zebra mussel and other invasive mussel species (*e.g.*, the Asian clam *Corbicula fluminea*, known nationwide; McMahon 1983; Leff *et al.*, 1990) have played a major role in the decline of other freshwater mollusks and are considered a threat to native endangered and threatened mollusk species (*e.g.*, Baker and Levinton 2003; U.S. Fish and Wildlife Service, 2003c). Thus, surveys are needed to assess the Hackensack and Passaic River watersheds' freshwater faunas and their critical limiting factors, and investigate the feasibility of re-establishing populations of rare mollusks (*e.g.*, federally and State-listed species) subsequent to improvements in water quality and storm water control.

Comprehensive surveys of the fishes throughout the HMD (*e.g.*, Kraus and Bragin, 1989; Bragin *et al.*, 2005) suggest that the fish community remains broadly impaired by poor water quality but may be recovering. Some tidal tributaries of the Hackensack River still experience hypoxic conditions periodically throughout the year (Neuman *et al.*, 2004). The 36 to 39 species of fishes identified in the above HMD-wide studies included only 45 to 61 percent of the 51 estuarine fishes reported as commonly occurring in New Jersey estuaries (Able, 1992; Able and Fahay, 1998) and about half of the species reported in the Meadowlands by Smith (1897). Many fishes reported as common throughout New Jersey estuaries (Able, 1992) were represented by 5 or fewer specimens (*e.g.*, Atlantic tomcod [*Microgadus tomcod*], Atlantic croaker [*Micropogonias undulatus*], striped searobin [*Prionotus evolans*], hogchoker [*Trinectes maculatus*], summer flounder [*Paralichthys dentatus*], naked goby [*Gobiosoma bosc*]) in the 480 collections of the most recent 2-year study in the Meadowlands (Bragin *et al.*, 2005). Not surprisingly, most abundant fishes in the recent survey of the Meadowlands (*e.g.*, mummichog, Atlantic silverside [*Menidia menidia*], gizzard shad [*Dorosoma cepedianum*]) are recognized for their tolerance of dynamic physicochemical conditions and pollution in estuaries (*e.g.*, Weis *et al.*, 1999b; Maryland Department of Natural Resources, 2005). Notably, Atlantic and shortnose sturgeons (*Acipenser oxyrhynchus* and *A. brevirostrum*) no longer occur in the HRW, despite the presence of a large population of the latter species in the Hudson River (National Marine Fisheries Service, 2004a). Fish collections in the Meadowlands also have consistently included such exotic fishes as carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*; Kraus and Bragin, 1989; Bragin *et al.*, 2005). The NMFS (2004b) has identified the Meadowlands as Essential Fish Habitat for 8 marine fishes of commercial importance (Table 29), including several popular food fishes such as black sea bass (*Centropristis striata*), bluefish (*Pomatomus saltatrix*), summer flounder (*Paralichthys dentatus*), and winter flounder (*Pseudopleuronectes americanus*). Because certain of these fishes likely experience slower growth rates (and presumably higher mortality) as a result of the chronic and periodic hypoxia and other stressors in the Meadowlands (*e.g.*, Bejda *et al.*, 1992; Hales and Able, 1995), improved water treatment has the potential to promote greater diversity and increased growth and production of fishes in the Meadowlands.

Table 29. Fishes for which the Meadowlands has been identified as providing Essential Fish Habitat (National Marine Fisheries Service, 2004b).

Common name	Scientific name
Butterfish	*Peprilus triacanthus*
Bluefish	*Pomatomus saltatrix*
Red hake	*Urophycis chuss*
Scup	*Stenotomus chrysops*
Black sea bass	*Centropristis striata*
Winter flounder	*Pseudopleuronectes americanus*
Summer flounder	*Paralichthys dentatus*
Windowpane flounder	*Scophthalmus aquosus*

Fishes with different feeding habits and prey are bioaccumulating certain contaminants in the Meadowlands (*e.g.*, Fernandez *et al.*, 2004; Weis, 2005). Such findings indicate: (1) a need for additional studies of contaminant bioaccumulation in the prey and predators of fishes in the Meadowlands, and (2) development of a comprehensive program targeting remediation and restoration of heavily contaminated and other aquatic sites. Young-of-the-year Atlantic tomcod collected in the Hackensack River had higher body burdens of dioxins and furans than tomcod collected anywhere in the HRE; the hepatic concentrations of dioxins and furans far exceed those known to elicit toxicity in tomcod and some other fishes (Fernandez *et al.*, 2004). In addition, although predatory fishes appear to be increasing in the Meadowlands, certain species (*e.g.*, white perch, *Morone americana*) contain high body burdens of mercury and PCBs (Weis, 2005). The Service recommends that bioaccumulation of certain contaminants (*e.g.*, mercury, PCBs) in fishes, their prey, and their predators be identified as a research priority critical to guiding remediation and restoration of the Meadowlands.

4. Amphibians

Amphibians in some areas are sometimes more abundant (*e.g.*, 70,000 per ha [Ovaska *et al.*, 2004]), contribute more biomass to terrestrial ecosystems than most mammals (Burton and Likens, 1975; Beebee, 1996), and are important components of both terrestrial and aquatic food webs and ecosystems (Hairston, 1987). Certain amphibians (*e.g.*, stream salamanders) have been recognized as keystone species[1] in wetland ecosystems (Wilbur, 1997; Kurzava and Morin, 1998; Wyman, 1998). Because they are sensitive to environmental change, many amphibians also are considered sentinel species[2]. Habitat loss, alteration, and fragmentation, contaminants, and illegal collecting are the likely causes of the low amphibian diversity throughout the HMD (Schlauch, 1976; Rouse *et al.*, 1999; Ovaska *et al.*, 2004; Rubbo and Kiesecker, 2005; AmphibiaWeb, 2005). Exotic species, including fungal pathogens (Berger *et al.*, 1998; Daszak *et al.*, 2003) have also been implicated in the extirpation of amphibians from some locales.

Ten species of frogs are the only amphibians that have been reported to occur in freshwater wetlands in the Meadowlands (Hackensack Meadowlands Development Commission, 1987; Kiviat and MacDonald, 2004), although there are unconfirmed reports of one salamander species occurring at one or more upland sites (W. Sheehan, pers. comm., 2005). Most, though not all, frogs that occur in the Meadowlands are common species with stable populations statewide (New Jersey Department of Environmental Protection, 2004f); however, most amphibians have been reported to be declining throughout the New York urban region (U.S. Fish and Wildlife Service, 1996a). Amphibians are not well studied in the Meadowlands; most species were reported by only one study conducted 20 years ago in a single locale. Their current status anywhere in the HMD is unknown. Recent surveys of the Teterboro Woods, which appeared to provide suitable habitats, recorded no amphibians (New Jersey Meadowlands Commission, 2004h).

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[1] Keystone species- a species that strongly affects community composition (biodiversity) and ecosystem processes.

[2] Sentinel species- a species sensitive to environmental change and environmental conditions; the presence of sentinel species indicates a relatively clean, undisturbed ecosystem.

The NJDEP (2004f) previously established the *Herp Atlas Project* to assess and protect amphibians (and reptiles) throughout the State. In support of this and other regional activities (*e.g.*, Amphibian Research and Monitoring Initiative; U.S. Geological Survey, 2005d) to protect amphibian biodiversity, efforts should be made to assess the distribution and abundance of amphibians in the HMD. Surveys of nocturnal calling and vernal pools are needed. Morphological (limb and development) and reproductive (intersex) data also should be gathered to assess contaminant and other environmental influences on the biology of amphibians in the HMD (*e.g.*, Crump *et al.*, 2002). Depending upon results of those surveys, additional steps to protect and sustain amphibians in the HMD (*e.g.*, roadway crossing structures, re-introductions, AmphibiaWeb, 2005) may be necessary, and would contribute to the Service's overall goal of sustaining diverse fish and wildlife resources in the Meadowlands. Forest amphibians may serve as keystone species; thus, the presence of amphibians may be important to re-establishing and sustaining a diverse palustrine community.

5. Reptiles

Reptiles are important predators and scavengers in many ecosystems, and often are recognized as indicator or sentinel species for entire regions. The presence of some reptile species may increase regional biodiversity; thus, certain reptiles (*e.g.*, snakes) serve as keystone species within an ecosystem (Bondavalli and Ulanowicz, 1999). While habitat loss, collecting, pesticides, and other factors have all contributed to the global loss of reptile biodiversity, habitat alteration may have greater adverse impacts on reptiles than on other terrestrial taxa (Gibbons *et al.*, 2000; Howes and Lougheed, 2004). Even subtle changes in microhabitat can directly alter: (1) behavior and site selection (Howes and Lougheed, 2004); (2) microclimatic conditions important for behavioral thermoregulation (Heatwole, 1977); (3) underground conditions of hibernacula (*e.g.*, stability, depth, humidity) that are essential for over-wintering (Rosen, 1991; Prior and Weatherhead, 1996), and (4) reproductive ecology (Shine *et al.*, 2002). Habitat alteration also affects the reproduction of many aquatic turtles, which increasingly must nest in comparatively small, unsuitable sites, closer to the water's edge, that have high nest predation rates (*e.g.*, Kolbe and Janszen, 2002; Baldwin *et al.*, 2004).

Of the 24 species of reptiles that occur in northeastern New Jersey, 15 species have been reported in the Meadowlands (Hackensack Meadowlands Development Commission, 1987; Kiviat and MacDonald, 2004). One reptile species often observed in the Meadowlands, the northern diamondback terrapin (*Malaclemys terrapin*), is reportedly declining throughout the entire state and elsewhere in the region. Historically, carcasses of vehicle-killed female terrapins, which were searching for nest sites, have been frequently observed along major roadways (*e.g.*, I-95) in the HMD in spring and early summer; in addition, nest predation in wetland restoration areas occurs frequently in the HMD (Spendiff, pers. comm., 2004). Roadways, nest predation, and contamination likely represent considerable sources of mortality for diamondback terrapin in the Meadowlands (*e.g.*, Roosenburg and Place, 1994; Wood and Hales, 2001; Gibbs and Shriver, 2002). The status of the mud turtle (*Kinosternon subrubrum*), stinkpot (*Sternotherus odoratus*), five-lined skink (*Eumeces fasciatus*), northern black racer (*Coluber constrictor*), and smooth green snake (*Opheodrys vernalis*) is unknown in the Meadowlands (New Jersey Department of Environmental Protection, 2004g). Several of those species have only been reported from a single site (Hackensack Meadowlands Development

Commission, 1987) and may be extirpated within the Meadowlands. One of the most common turtle species in the Meadowlands, the red-eared slider (*Trachemys scripta*), was introduced from the pet trade (Kiviat and MacDonald, 2004).

The NJDEP (2004g) recently established the *Herp Atlas Project* to assess the distribution and abundance of reptiles (and amphibians) throughout the State. To further this effort, the distribution and abundance of reptiles and their critical habitats (*e.g.*, potential den areas such as Snake Hill and Little Snake Hill, nesting sites of the diamondback terrapin) in the HMD should be determined. Available information suggests that additional protective measures should be considered for terrapins (*e.g*., roadside fencing to reduce mortality of nesting females) and snakes (*e.g.*, protect known den areas). Creation of nesting areas for diamondback terrapins has been suggested previously as a potential restoration activity in the Meadowlands (U.S. Fish and Wildlife Service, 2004e) and is being undertaken in other mid-Atlantic states (*e.g.*, Maryland). Rearing and release programs are being used elsewhere in New Jersey in part to rebuild terrapin populations (Herlands *et al.*, 2004). Development of such a program in the Meadowlands would provide a valuable educational program, and would additionally support efforts to understand contaminant effects in the Meadowlands (*e.g.*, as has been done with studies of the mummichog in polluted and non-polluted wetlands; Weis and Weis, 1989; Khan and Weis, 1993).

6. Birds

Birds are among the most conspicuous components of ecosystems throughout North America and the world, and exhibit diverse feeding (*e.g.*, granivory, carnivory) and reproductive behavior, including nest parasitism[3]. Their endothermy[4] and ability to fly have enabled birds to exploit resources at spatial scales that exceed most other groups of animals and contributed to the evolution of lengthy spring and fall migrations between distant nesting and wintering grounds. Birds also are recognized as keystone species in some ecosystems (*e.g.*, Payton *et al.*, 2002).

Birds are increasingly viewed as imperiled worldwide, including North America (Rich *et al.*, 2004). Approximately 40 percent (more than 330 species) of the 800+ species of migratory birds on the Atlantic flyway use the Meadowlands as breeding habitat or as a "stopover" in which to feed and rest during their spring and fall migrations (Kane *et al.*, 1991; Kane and Githens, 1997). This diversity includes year-round resident species that breed in the Meadowlands, migrant species that pass through the Meadowlands in spring or fall, and a small group of species that overwinter there during their non-reproductive season. Because birds in the Meadowlands are diverse, occasionally abundant, generate considerable public interest, and are a federal trust resource responsibility, migratory birds provide a strong justification for the protection and restoration of the Meadowlands.

A preliminary study (Siegel *et al.*, 2003) indicates that restoration has the potential to increase the diversity of birds that use the Meadowlands for breeding. Avian species richness increased

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[3] Nest parasitism- where an individual of one species (e.g., cowbird [*Molothrus ater*]), places its eggs in the nest of another species (*e.g.*, eastern Meadowlark).

[4] Endothermy- the ability to generate heat and metabolically regulate internal body temperature; animals (*e.g.*, mammals) with this capacity are sometimes referred to as "warm-blooded."

during the years following the restoration of the Harrier Meadow. Pre-restoration bird communities were similar throughout Harrier Meadow marshes and showed little inter-annual variation; in addition, unrestored portions of the Harrier Meadow marshes had similar bird communities pre- and post-restoration. In contrast, restored portions showed considerable changes in the bird community composition and guild structure (landbirds, waders, waterfowl, raptors, gulls/terns, and shorebirds). The greatest change in bird community composition occurred during the first post-restoration year as increased habitat heterogeneity attracted more bird species; however, bird diversity continued to increase in succeeding years. This preliminary information is encouraging, but also indicates the need for additional site information (*e.g.*, contaminant monitoring) to evaluate the potential for Harrier Meadow and other restored sites to function as attractive nuisances and population sinks.

Thus, Service-recommended actions to support and maintain avian biodiversity include remediating contaminated sites and improving water quality to increase habitat quantity and quality. These actions are critical to providing for the long-term protection and support of birds residing in and migrating through the Meadowlands. Remediating contaminated sites and improving water quality have beneficial effects on all fish and wildlife resources in the Meadowlands, including birds. Because of their food preferences and trophic position, piscivorous and insectivorous birds are especially vulnerable to bioaccumulation and biomagnification of contaminants such as mercury (Evers *et al.*, 2005). However, while the presence of different species of birds in the Meadowlands is well-recognized, most aspects of the biology of birds in the Meadowlands are poorly known. Acquiring additional information about (1) contaminant impacts on select bird species (*e.g.*, belted kingfisher, *Ammodramus* and *Melospiza* sparrow species, red-winged blackbirds, herons, and rails), (2) urban landscape impacts (*e.g.*, buildings, radio towers, automobiles) on birds, and (3) habitat-specific life history is critical to providing for the long-term protection of avian species that reside in or migrate through the Meadowlands.

In addition to actions that will protect and sustain all bird species, the Service recommends considering actions to support rare bird species, including federally listed and State-listed species, and other declining or vulnerable species on various special concern or watch lists (Tables 8, 9, and 10). For example, the federally listed (threatened) bald eagle has been increasingly observed in the Meadowlands during fall, winter, and spring. However, the bald eagle neither nests nor is regularly seen at many sites; perhaps few foraging perches and roost sites are available. Prior to providing (or supporting applications to provide) any artificial perch or roost structures to encourage the re-establishment of bald eagle or other bird species in the Meadowlands, the Service must consider potential impacts from the "built landscape," as one bald eagle is known to have died from a mid-air collision in the Meadowlands. Available information regarding State-listed bird species is limited, but indicates that breeding populations of most of those species in the Meadowlands are small and limited to few sites. The status and needs of rare bird species breeding in the Meadowlands should be assessed; depending upon the results of such species and needs assessments, programs should be implemented to protect those species and species groups and educate the public regarding their biology, needs, and threats. The source and extent of potential contaminants and their availability and effects must be evaluated when considering establishment of programs to support listed and other rare species (*e.g.*, State's Wildlife Action Plan).

7. Mammals

Because of their size, abundance, endothermic physiology, and other features of their biology, mammals often have major impacts on many ecosystems, including wetlands. Because of their endothermy, mammals must consume larger amounts of food than ectothermic[5] animals and strongly influence the transfer of materials and energy through wetland and upland ecosystems. For example, herbivorous mammals may increase or decrease plant diversity, physically alter the landscape, and redistribute nitrogen and other nutrients through their waste (Huntly, 1991; Rooney and Waller, 2003). Small predaceous mammals such as bats, shrews, and moles are important predators of insects and other invertebrates (Chapman and Feldhammer, 1992). Small mammals also are important prey items for a number of other animals, including reptiles, birds, and certain mammals (*e.g.*, red fox [*Vulpes vulpes*]). Just through these predator-prey relationships, small mammals may directly influence population levels of other animals, such as insect pests (*e.g.*, gypsy moth [*Porthetria dispar*]; Jones *et al.*, 1998; Schauber *et al.*, 2004), disease vectors (*e.g.*, deer tick [*Ixodes scapularis*]; Giardina *et al.*, 2000; Goodwin *et al.*, 2001), and raptors (*e.g.*, sharp-shinned hawk [*Accipiter striatus*], Schmidt and Ostfeld, 2003). Mammals also may modify the physical environment in ways that create habitat for other animal species, and thus are recognized as keystone species of certain ecosystems.

Approximately 24 mammal species have been reported in the Meadowlands (Hackensack Meadowlands Development Commission, 1987; Kiviat and MacDonald, 2004). Most mammal species common in uplands and wetlands of the Meadowlands are recognized for their tolerance of urban environments but have not been well-studied in such areas (Kiviat and MacDonald, 2004). These species include the eastern cottontail (*Sylvilagus floridanus*), white-footed mouse (*Peromyscus leucopus*), meadow vole (*Microtus pennsylvanicus*), common muskrat (*Ondatra zibethicus*), and the four introduced species known to have feral populations in the Meadowlands (house mouse [*Mus musculus*], Norway rat [*Rattus norvegicus*], dog [*Canis familiaris*], and cat [*Felis domesticus*]). Populations of house mice and Norway rat have likely declined with landfill closures (Kiviat and MacDonald, 2004); however, feral cats remain likely to have adverse impacts on wildlife populations in the Meadowlands. Muskrats have been identified as a probable keystone species in the Meadowlands (Kiviat and MacDonald, 2004). White-tailed deer (K. Spendiff and R. Feltes, pers. comm., 2004) and coyote (*Canis latrans*; K. Spendiff and B. Mohn, pers. comm., 2004) have been reported recently in the Meadowlands. As the deer population grows in the Meadowlands, so will the need to manage this species.

The Service seeks to sustain or increase the biodiversity of all taxa, including mammals; however, it is unclear to what extent the Meadowlands may be capable of supporting additional mammalian species. For example, the Meadowlands lies along the edge of the range of foraging habitat of the Indiana bat, a federally listed (endangered) species; however, suitable roosting habitat (*i.e.*, trees with loose bark in summer and caves or mines during winter; U.S. Fish and Wildlife Service, 1999) does not occur in the Meadowlands.

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[5] Ectothermic- when environmental temperature primarily influences body temperature, sometimes referred to as "cold-blooded"

One mammal species that may deserve consideration for establishment in the Meadowlands is the State-listed (endangered) Allegheny woodrat (*Neotoma magister*), which also is listed as threatened by the State of Pennsylvania (Pennsylvania Game Commission, 2005) and endangered by the State of New York, where it is believed extirpated (New York State Department of Environmental Conservation, 2003). The last remaining population in New Jersey occurs in Bergen County along the Palisades (New Jersey Department of Environmental Protection, 2005a). The presence of other populations, even isolated ones in the Meadowlands, would improve the long-term survival of the species in the region. Efforts to establish populations in other areas of apparently suitable habitat have been unsuccessful (M. Valent, pers. comm., 2005). It is unclear if the rock outcrops in the HMD (*e.g.*, Snake Hill, Little Snake Hill) provide sufficient habitat or if raccoon roundworm (*Baylisascaris procyonis*), a common parasite of northern raccoon (*Procyon lotor*) responsible for the extirpation of Allegheny woodrat in neighboring states, is prevalent in the area.

Reducing adverse impacts of non-native mammal species in this urban area is another Service objective. To accomplish this objective, the Service recommends: (1) monitoring and assessing the status of introduced or feral mammal populations, (2) monitoring pathogens and disease vectors of selected mammal populations, and (3) educating the public regarding non-native mammal species, such as the domestic cat. Management plans and accompanying public education programs are needed to address the adverse impacts of those species.

E. SUMMARY

Considerable progress has been made during the past few years by the NJMC and the MCT in acquiring wetlands in the HMD; however, acquisition of wetlands elsewhere in the HRW and of upland open space throughout the watershed has progressed slowly. This may result from a lack of information on the distribution, composition, and value to fish and wildlife of such wetland and upland habitats. Acquisition of remaining wetlands and other open space throughout the HMD and the watershed is critical to safeguarding and sustaining the Meadowlands and its biodiversity.

All levels of government (federal, State, and local) have important roles in protecting the Meadowlands ecosystem and its fish and wildlife resources. Implementation of current laws and regulations pertaining to wetlands has been inconsistent and resulted in lapses in the protection of wetlands and fish and wildlife resources throughout the HMD. Federal, State, and local laws and regulations should be reviewed to ensure consistency and improve protection for fish and wildlife resources. Stakeholders should pursue designation of the Meadowlands as a marine protected area to promote and provide comprehensive long-term protection.

Restoration activities in the Meadowlands to date appear promising; current activities have shown the potential for restoration to reduce and in some areas eradicate common reed and promote increases in native biodiversity. Efforts to restore the Meadowlands and protect its fish and wildlife populations must include a comprehensive program to integrate and address hydrologic (*e.g.*, river flow, stormwater control, SLR) and contaminant concerns (*e.g.*, industrial contamination, landfills, sewage treatment). Similarly, the impacts of the urban landscape upon fish and wildlife populations must be addressed. Many of the historical adverse impacts on fish and wildlife populations can be reversed through: (1) restoration, (2) adaptive management based on monitoring of existing restoration projects, and (3) incorporating urban ecology in future project planning throughout the HRE. In some instances, active management and manipulation of fish and wildlife populations and their habitats likely will be necessary.

Establishment of diverse vegetative communities comprised of native species is a major Service objective for the Meadowlands. Plant diversity in wetlands and uplands can be improved substantially by eradicating common reed, planting desired species, allowing re-colonization by native species, monitoring on-site vegetation, and treating common reed that re-invades sites before it becomes re-established. Although restoring the Meadowlands to its former condition (*i.e.*, forested extensively by Atlantic white-cedar) is unrealistic given the watershed's current hydrology, increasing the extent, diversity, and native composition of its wetlands is vital to sustaining and safeguarding the region's fish and wildlife resources. Increasing the extent and quality of upland buffer areas also will promote the recovery of wetland vegetation and the functioning of restored wetlands, as well as provide upland habitat for other species such as migratory birds. An increase in upland vegetative diversity will also better sustain animal diversity in uplands and adjoining wetlands.

The Meadowlands retains considerable biodiversity despite the extirpation of species that historically occurred there, a testament in part to the resiliency and adaptiveness of many species. Available information, though limited for many taxonomic groups, indicates that aquatic and terrestrial communities of invertebrates, fishes, amphibians, reptiles, birds, and mammals remain imperiled by water quality, contamination, and other stressors (*e.g.*, invasive species). Populations of many species of these groups have been identified as keystone species; thus, programs targeting the re-establishment of populations of those species may further assist the recovery of biodiversity and restoration of the Meadowlands ecosystem.