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# The Dyke Marsh Preserve Ecosystem

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ABSTRACT

For over a century, Dyke marsh along the Potomac River just south of Alexandria, VA, has been a favorite site for natural history studies. Despite earlier attempts at diking to create agricultural land and dredging for sand and gravel, the remaining marsh represents the last major tidal freshwater wetland on the upper Potomac River, and is now owned and maintained by the National Park Service as the Dyke Marsh Preserve. In the present paper historical data on physical properties and biota are compared and contrasted with more recent biological investigations to show functioning ecosystem components, interrelationships among the flora and fauna, and documented changes in biotic communities over the years. As a haven for migratory waterfowl and shorebirds, unique plant communities, and large, dynamic insect and vertebrate populations, the Preserve is constantly threatened by river pollution, nearby large-scale development projects, and bridge construction. The long-term stability of this unique Preserve depends largely on the vigilance of the Park Service, concerned citizens, and environmental groups to ensure the preservation of this valuable functioning ecosystem.

Key Words: Ecosystem; Freshwater Wetland; Biotic Communities; Floodplain.

## INTRODUCTION

Wetlands, whether they be marshes, swamps, or floodplain forests, are habitats that support a diverse group of aquatic or semi-aquatic plants and animals. Wetlands play an integral role in maintaining the quality of life through material contributions to a region's economy, food supply, water supply and quality, flood control, wildlife habitats, and as "carbon sinks." They buffer shorelines from erosion, filter sediments and contaminants from the water column, and serve as a basic nutrient source, chiefly in the form of decaying organic material, for microorganisms and animals in the food chain. Wetlands are also crucial feeding, breeding, and nursery sites for hosts of fish and waterfowl. Bird-watching, boating, and fishing are popular contemporary recreational uses of wetlands. Additional values of wetlands are discussed in Odum (1983).

National interest in wetlands was set forth in the findings of the Emergency Wetlands Resources Act of 1986 in which the Congress found that wetlands are known to play a vital role in maintaining environmental quality. Thus, they contribute to the overall health, safety, recreation, and economic well-being of all citizens of the Nation.

From the 1780s through the 1980s, Virginia's wetlands were reduced from an estimated 1.85 million acres to 1.07, a 42 percent loss, most of these converted to agricultural land. Although the rate of conversion has slowed in recent years, wetland losses continue to outdistance gains. According to the Council on Environmental Quality report (1996), over the past 25 years "the key factor driving the dramatic change in wetlands losses, has been the enactment of laws and implementation of federal, state, and local programs that protect and restore wetlands." An example is enactment of the Clean Water Act of 1972. Even so, many of the remaining wetlands have declined in quality because of nutrient loading, altered hydrology, and urban encroachment.

Wetlands along the Potomac River are commonly found within or associated with its tributaries. For example, the largest remaining freshwater tidal wetland in the Washington area, Dyke Marsh Preserve (DMP), is representative of the Potomac watershed wetlands of 200 years ago. It lies in the littoral zone of the Potomac estuary with cattails forming the dominant vegetation cover over most of the marsh. Because of its proximity to metropolitan Washington, DC, the marsh has been a favorite spot for naturalists and fishermen for at least 100 years. Although heavily impacted by typical urban pressures, such as air and water pollution, invasion of exotic plants, and population spread, the preserve remains as one of the largest wetlands adjacent to the Nation's Capitol.

Although salt marshes have been intensely researched for decades, tidal freshwater wetlands have, for the most part, been ignored by limnologists. In a review of the two ecosystems, Odum (1988) pointed out (p. 170) "...while the basic structure and processes are the same in the two environments, significant differences do exist in species numbers and composition and in the pattern, rates, and end products of many of the processes." Specifically, numbers of intertidal vascular plants, reptiles, and amphibians decline dramatically between tidal freshwater and salt marshes. Other groups, such as macro algae, invertebrates, and fishes increase. Although salinity plays an important role in most of the differences between the two environments, other factors (sulfide, species/area relationships) operate in a synergistic fashion and should be included in a thorough analysis.

Furthermore, mud flats of the tidal freshwater marshes are mostly covered with water during high tides and seasonal river flooding, and many may be covered with fleshy macrophytes in summer. Recent changes in submersed aquatic vegetation can be associated with nutrient enrichment or "eutrophication" of the river by fertilizers, sewage, and pollution coming from upstream.

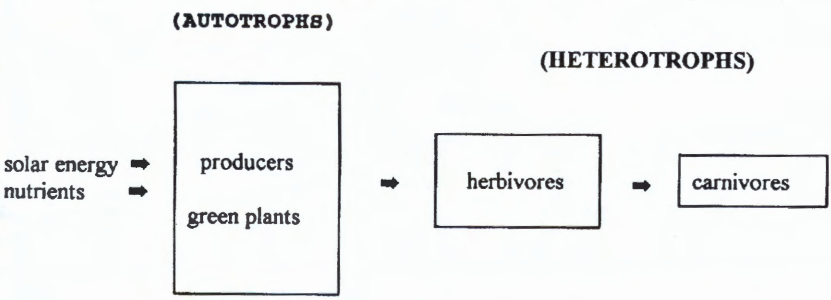
To understand the intricate biological and physical interactions in the tidal freshwater DMP, it is treated here as an example of a wetland ecosystem, a basic functional unit in ecology. The ecosystem conceptually includes both the living and nonliving environment, each influencing the properties of the other and both necessary for maintenance of the system. In this report, attention will be given to the fundamental living and nonliving components and their interrelationships in DMP. A caveat--for some components of DMP, data are sparse, so additional studies are needed.

## THE ECOSYSTEM CONCEPT

Living organisms and their nonliving environments are inseparably interrelated and interact with each other. The ecological system (or ecosystem) includes all of the communities of organisms in a given area interacting with their physical environment so that energy flow leads to clearly defined trophic structure, biotic diversity, and material cycles (i.e., exchange of materials between living and nonliving parts). From the trophic standpoint, an ecosystem has two components: (1) an autotrophic component, in which fixation of light energy, use of simple inorganic substances, and buildup of complex substances predominate; and (2) a heterotrophic component, in which utilization, rearrangement, and decomposition of complex materials predominate. For descriptive purposes, it is convenient to recognize the following components as comprising the ecosystem: (1) inorganic substances involved in material cycles, (2) organic compounds that link the biotic and abiotic, (3) climatology, (4) producers, chiefly green plants which manufacture food from simple inorganic substances, (5) macroconsumers (heterotrophic organisms, chiefly animals that ingest other organisms or particulate organic matter), and (6) microconsumers (heterotrophic organisms chiefly bacteria and fungi which break down the complex compounds of dead protoplasm, absorb some of the decomposition products, and release inorganic nutrients that are usable by the producers together with organic substances).

One of the universal features of all ecosystems, whether terrestrial, freshwater, or marine, is the interactions of the autotrophic and heterotrophic components. To understand these interactions, it is necessary to identify the following: (1) energy pathways, (2) food chains and webs, (3) diversity patterns in time and space, and (4) nutrient cycles,

A generalized energy flow through an ecosystem follows (much energy is lost from the system at each transfer) (adapted from Odum 1997).




Food chains are of two basic types: grazing food chain which, starting from a green plant base, goes to grazing herbivores and on to carnivores; the detritus food chain which goes from dead organic matter into microorganisms and then to detritus-feeding macroorganisms and their predators. Food webs integrate several food chains to reveal alternate pathways (Odum 1997).

## DESCRIPTION OF THE DYKE MARSH AREA

Just below the City of Alexandria, the DMP/Belle Haven area consists of approximately 550 acres of developed parkland, river shoreline, and marsh. This area, east of the George Washington Memorial Parkway, is managed by the U.S. National Park Service (Fig. 1). In addition to a large and significant remnant wetland habitat (DMP), a developed area known as Belle Haven includes a marina and picnic area. Situated in Fairfax County, Virginia, the park area extends from the Alexandria City line south along the Potomac River for 2 ½ miles (Fig. 2). The mouth of Hunting Creek is on the northern boundary; Belle Haven Country Club is adjacent to the northwest boundary; Morningside Lane and Wellington Heights are located along the southern boundary; and Belle Haven Community, Westgrove, Marlen Forest and Villamay communities are on the western boundary.

Aquatic habitats associated with the tidal reaches of the Potomac River include unvegetated subtidal bottoms, intertidal flats, submerged aquatic vegetation, emergent

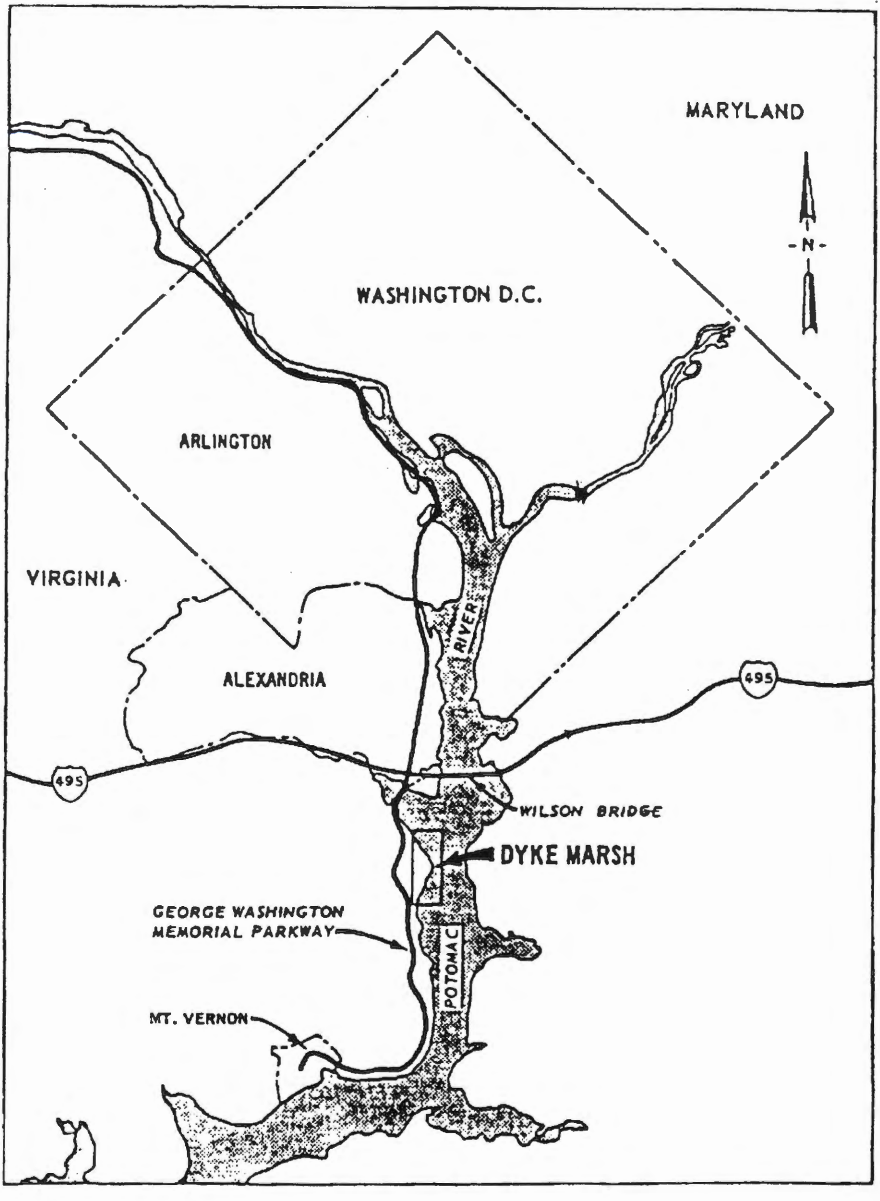



FIGURE 1. Location Map of Dyke Marsh.

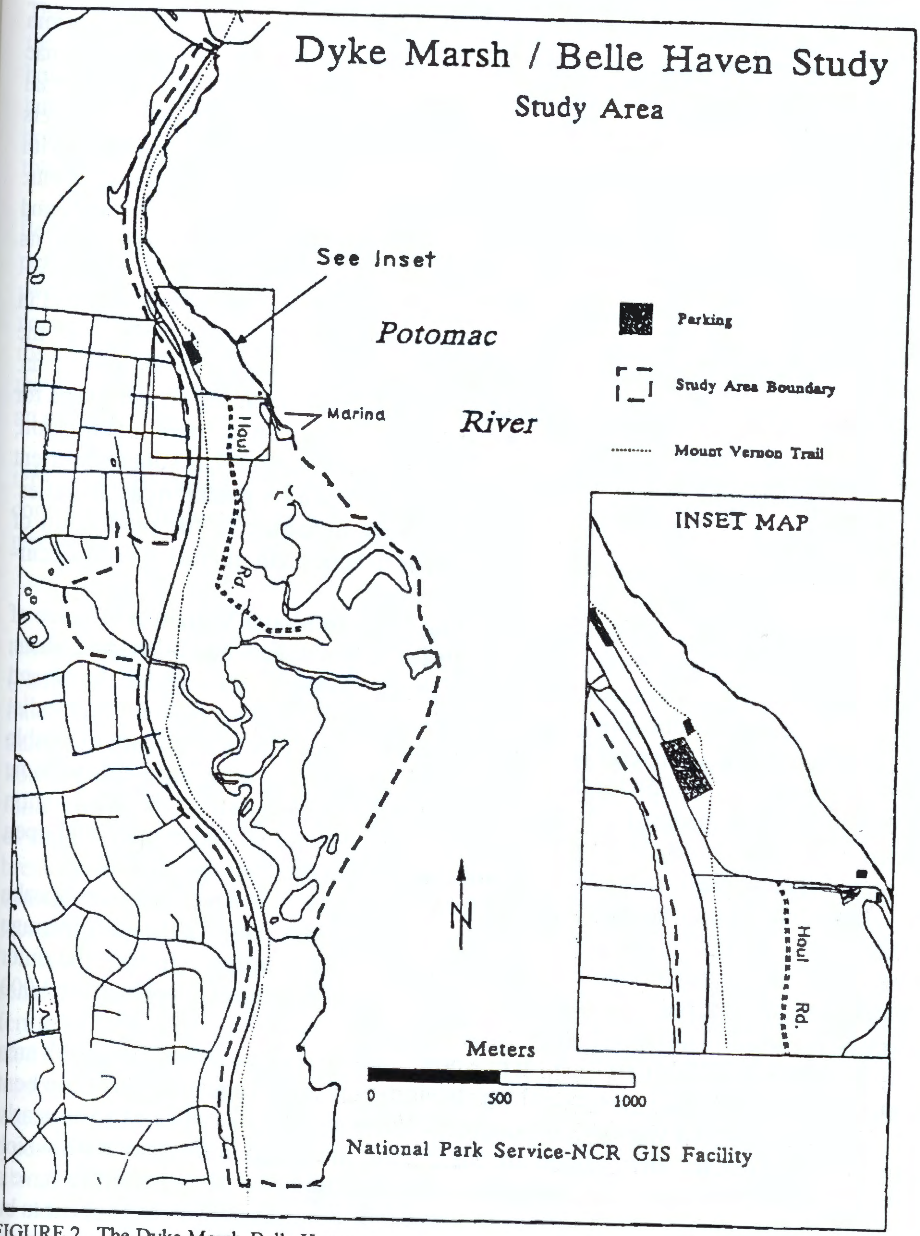



FIGURE 2. The Dyke Marsh-Belle Haven area.

marshes, and forested wetlands. Non-tidal waters are restricted to both modified/natural stream channels and woodland ponds.

Hunting Creek was undoubtedly a dominant factor in the formation of DMP through its deposition of sediment and diversion of stronger river currents away from the Preserve. The force of the creek has been muted as its confluence with the Potomac River has been boxed in with the construction of the George Washington Memorial Parkway, the Capital Beltway, Belle Haven Country Club, and Hunting Towers apartment complex. The creek was described in 1918 by W. L. McAtee as filled with aquatic vegetation and having an interesting flora with peculiar marsh and mud plants. But much of this has changed. Buildings and roads now sit on former wetlands and sewage effluent from the City of Alexandria and Fairfax County is discharged into its waters (Thomas 1976).

Nonetheless, one of the largest mudflat areas along the Potomac River is found in the Hunting Creek embayment which generally extends from the area south of the Route 1 interchange east to Jones Point Park and south to the Belle Haven marina. These mudflats perform important ecological functions by providing foraging sites for migratory and resident birds, fisheries habitats and nurseries, nutrient assimilation, maintenance of water quality, and floodflow attenuation. Mud flats contain nutrient rich sediments which support bacterial, phytoplankton, and zooplankton communities. The presence of these communities is particularly important to the production of benthic invertebrates and subsequent richness of fisheries and migrating birds occurring in the region.

Since at least 1878, the area from Hunting Creek to Mount Vernon, a distance of about eight miles, has been a favorite resort for bird-watchers and other naturalists. However, in the 1950s extensive dredging of the soils underlying the marsh threatened its existence. Vigorous lobbying efforts by members of the Audubon Naturalist Society led to the Congressional action which set aside DMP as an "irreplaceable wetland" on June 11, 1959 for the protection and preservation of wildlife. At that time DMP was one of the last freshwater tidal marshes remaining within the Washington Metropolitan area. It included upland forest, wetland (forested and marsh), and open water, and comprised an area of about 400 acres, about one-half its original size.

Less than 100 miles from the confluence of the Potomac River and Chesapeake Bay, DMP is strongly influenced by the Bay's tides. At the Preserve the daily average three-foot tide cycles are more important than the river's current. In fact, the outer reaches of the Preserve are separated from the 25-40'-deep ship channel by over 2,000 feet of a shallow plateau.

In their view of DMP in 1963 Myrick and Leopold reported it as: "The marsh area appears uniformly flat to the eye. In early spring the dried vegetation has been bent over by snow [winter weather], so that at low tide one can walk with ease over nearly the full unchanneled area. There are some small areas within the marsh on which timber is the primary cover. Though some of these timbered areas appear to have a slightly higher elevation than average for the marsh, other timber patches appear to be flooded regularly. By midsummer, the marsh vegetation is thick and green, standing at least knee high."

Much of the emergent marsh lies on a plateau at about 4 feet above mean low tide and thus is not inundated by the usual three-foot tidal cycles. Despite this relative lack of major topographical relief, even these minor differences in elevation have a marked effect on the vegetational zones of the wetlands. Earlier dredging activity extended deep enough into the extant marsh to create a direct connection of the two major guts. The result has been the creation of two islands out of what was originally portions of the intact marsh. Several deep holes up to 30 feet below mean low tide exist. These holes are gradually filling by deposition, but it can be conservatively estimated to take hundreds of years of deposition before ongoing sedimentation could bring the entire bottom back up to the previously undisturbed levels. Dredging also eliminated at least two tidal guts with their associated ecosystem dynamics.

DMP can be divided into three major zones or communities: the marsh proper, the floodplain forest, and the swamp forest. The marsh proper, which comprises about 35 percent of the area, is partially underwater except at low tide. The floodplain and swamp forest are about 4 feet above mean high tide and are not inundated during the normal tidal cycles. However, the tide does carve deep fingers, called "tidal guts," into the land. Occasionally, strong easterly winds coupled with an incoming tide can flood the marsh for several hours. The swamp forest is a depressed area possibly formed by an old river bed.

Estuarine systems, such as those found in the tidal freshwater DMP, characteristically possess higher concentrations of nutrients than the Chesapeake Bay or contributing freshwater systems. These features will be discussed in detail later in this report.

## CLIMATOLOGY

The climate of DMP-Belle Haven area is typical of the Washington, DC region: temperate with strong seasonal patterns and fairly evenly distributed precipitation (National Park Service 1976). Average annual precipitation is 40 inches, of which as much as 12 inches might be in snowfall. Heavy rainfall may occur during summer thunderstorm events, particularly when tropically derived. Summers are warm and humid (July mean daily maximum is 88° F) and winters are mild (January mean daily minimum is 28° F). These temperatures are tempered because of the moderating effect of the Potomac River. Easterly to southerly winds create surface waves which can break on an exposed shore, thus contributing to shoreline erosion. Infrequent major coastal storms and boat waves can create periods of stronger wave action. The wooded islands at the northern end protect the marsh against the winter's northwesterly winds.

These climatic conditions combine to give the DMP area a relatively long growing season of approximately 208 days. Generally, the favorable weather conditions and fertile soils not only encouraged farming during the agricultural era, but also contributed to the regrowth of forests after farming faded as a livelihood. Vegetational response to seasons because of slower water temperature change is evident as the marsh vegetation is generally slower to initiate growth above the soil surface than dry land types in the spring but remains longer in the fall. Much of the woody vegetation on islands in the marsh is probably the result of earlier diking and agricultural uses.

Air quality in the DMP area is similar to that along the Potomac River from Washington, DC southward (Wester and Sullivan 1970). The principal pollutants are oxidants (ozone) derived from sunlight interaction with carbon combustion compounds from vehicles (photochemical oxidants). No information exists relating air pollution episodes (which occur during periods of low wind and upper atmospheric inversion) to vegetation stress at DMP, although such correlations may exist.

## HISTORY

Before Europeans came, this part of northern Virginia supported a variety of plant communities such as oak-pine and other forests which formed the habitat for abundant wildlife, ranging from black bears and mountain lions to chipmunks and mice, and from eagles and wild turkey to passenger pigeons. Marshlands began evolving in the shallows of Pleistocene deposits at DMP at least 5,000 to 7,000 years ago (National Park Service 1976). A succession of cultural groups occupied and abandoned the area. By the early 1700s, explorers recorded numerous Indian villages along the banks of the Potomac River in the area south of what is now Alexandria. Hunting Creek appears first on a map drawn in 1731. Some of the tribal names reported from this area were Nameroughquera, Assomeek, Namasingaheut, Tauxenent (near Mount Vernon) and Doeg or Dogue. These Indians cultivated the bottom lands along the Potomac River, growing mostly corn but also peas, pumpkins, gourds, potatoes, mayapples, squash and tobacco. They also hunted game in the forests, trapped fish with fish weirs along the river and collected mussels from the creeks (Parsons et al. 1976).

As European colonization increased, the colonists cleared the original forests for lumber and farmland, and many dirt roads were made. All this activity undoubtedly led to siltation of the streams. The earliest settlers also must have chased out or killed bears, elk, and mountain lions in the area. Wolves were still present as late as 1782. It is also likely that trapping affected beaver and muskrat populations.

Originally the Dyke Marsh area was part of a vast land grant known as the "Northern Neck" made in 1688 by Charles II of England to Thomas, Lord Culpeper and six other noblemen. Over 5 million acres of this property came into the ownership of Thomas, Sixth Lord of Fairfax in 1735 and, after selling part, he placed his cousin Colonel William Fairfax in charge of managing his estate. Some of the earliest land grants in Fairfax County were made in these watersheds in 1657 and other large grants were made here in 1674 and 1678. Large-scale land changes did not take place until about 1690-1710.

By the 1790s, the Potomac River at the latitude of the present White House was nearly a mile across, over twice its present width. Tiber Creek emptied into the river near the present Lincoln Memorial, and the main channel of the river cut through on the west side of Analostan (Roosevelt) Island. By the mid-1880s, large marshes and shallows had developed on both sides of the river, at least in part from silt washed down the river from upland farms and cut-over woodlands upstream. Wild rice, wild millet, and smartweeds covered these marshes, thus making them ideal waterfowl habitats. By 1950, chiefly because of dredging and filling, few of the marshes remained (Slavik and Uhler, 1951).

In the 1930s, the area to the south of Alexandria was also experiencing a surge in growth and development. "Belhaven," which was the earliest permanent English settlement in what was to become Fairfax County, has an interesting recent-day history. A single immigrant family was responsible for much of the early 20th century development in the Belle Haven watershed. Augusta Olmi, a stone mason from Italy, arrived in the United States just after 1900. His family settled in Pennsylvania, and his son Eugene, who became an entrepreneur in real estate development, made his first million by the age of 25. Depression losses in the 1930s spurred the family to move to Virginia where Olmi began building once again. Of the 380 homes in the Belle Haven community today, over 300 were built by the Olmi father-and-son team.

Development in the watershed began in earnest in the late 1940s as housing construction accelerated dramatically after World War II. Today most of the watershed is developed into private homes, apartments or commercial areas with the exception of the area east of the George Washington Memorial Parkway.

It is believed that DMP originated from the sediment dropped as the current from Great Hunting Creek lost velocity upon reaching the mainstream of the Potomac River. Hunting Creek and especially its mouth play an important role in the existence of DMP. In addition to deposition, the marsh depends upon periodic flushing and scouring from the Potomac River floods which maintain this dynamic freshwater tidal system and retard succession to a wetland forest.

In the early 1800s one of the first colonial land owners of the marsh, Col. Augustine J. Smith of Westgrove Plantation, sought to increase his land holdings for grazing and perhaps real estate purposes through the establishment of a perimeter of earthen dikes in the shallow waters around Dyke Marsh (Edith Sprouse, pers. comm.). Two series of dikes had been placed in the marsh. One dike project was for reclaiming land for agricultural purposes from bottom land and pocosins; it apparently consisted of a large ditch dug shortly after the Revolutionary War that runs southeast from near Belle Haven across the emergent marsh to the river with strategically located embankments made from gravel obtained from the nearby hill. Vandals disrupted this system, but the remnants of one of the embankments which crossed Hog Island gut can be seen in the vicinity of that stream and the George Washington Memorial Parkway. The other dike project was a shad fishery with the embankments of gravel and brick placed in the submerged marsh. The placement of these dikes are well shown on a 1917 U.S.G.S. map and remnants can still be seen around the edge of the open marsh. Eventually trees began growing on the dikes. Parts of these outer embankments are still in evidence today. The quality of the wet meadow established did not justify the efforts necessary to maintain the dikes because breaches (beneficial to fishermen) were left unrepaired in sections of the dike; these led to more tidal guts into the wetlands. The tidal guts, along with the thickly growing wetland vegetation formed an almost impenetrable area to such an extent that it became popularly known as "Hell Hole" (National Park Service, 1976).

A dramatic description of "Hell Hole" appeared in the Alexandria Gazette of 10 August 1858. The article ("A Sporting Ground") read in part: "It is a vast expanse of mud, stumps, water-plants, and water, with here and there a narrow strip of dry land, just sufficient to afford a dwelling place for its terreous inhabitants, girted by a worn-out embankment--for an attempt was made many years ago to reclaim it--the outer margin of which is washed by the waters of the Potomac river, Hunting and Muddy Creeks, while along the entire length of its inner border grow in rank luxuriance, and close set, large and tall water-oaks and sycamores, among the exposed and twisting roots of which can be seen at this season many beautiful varieties of the marsh snake....Hell Hole is a grand, wild place, and, save for the miasm and mosquitoes which reign there pre-eminent, would be a magnificent abode for those fond of following the pursuits of Nimrod and Walton."

By the first quarter of the 20th century Smoot Sand and Gravel Corporation (SSGC) gained ownership of the southern portions of the marsh from Bucknell University. The northern end was transferred to the Department of Interior from the Department of Agriculture along with responsibility for the George Washington Memorial Parkway. By 1940, SSGC commenced dredging in open water areas for the valuable Pleistocene sand and gravel beds which lay in a thick layer from 16 to 40 feet deep. The dredging encroached onto emergent wetland sections and by the early 1950s wildlife enthusiasts became concerned. It was not until 1959, however, that largely through the efforts of Congressmen Reuss and Dingell was it possible to reach an agreement with SSGC which would ultimately lead to cessation of dredging and protection of significant portions of the marsh.

The arrangements were formalized in PL-86-41 (June 1959). This law conceded rights for continued dredging in specified areas of the marsh, including those under the jurisdiction of the Department of Interior for 20 and 30 year periods, in return for ownership by the United States of the major Smoot properties.

Exchange of properties, however, dragged on for several years. According to Briggs (1954): "For a decade, at the request of natural history societies, the Smoot Company has refrained from substantial operations in the Dyke area; it has offered at financial sacrifice to exchange its Dyke acreage for other government lands with equivalent deposits. But lack of agreement among government departments has blocked a solution. Unless effective action is soon forthcoming, no one will criticize the Smoot Company if it is compelled to continue its dredging."

In a review of the situation, The Sunday Star, Washington, DC., July 19, 1970, noted: "At issue is a million-dollar land swap between the Interior Department and the Richmond, Fredericksburg, and Potomac Railroad. After 35 years of haggling, the railroad has obtained access to the George Washington Memorial Parkway from an oddly shaped 42-acre chunk of land locked between the Potomac Yard and the Parkway near National Airport. Without access, the land has not been usable. In return, the Park Service has received 28 acres of swamp and underbrush at the southern end of the marsh, farther down the Parkway near Mount Vernon. The marsh is considered a priceless haven for waterfowl.

The 28-acre property is owned by Charles Fairchild, an Alexandria developer who will lease the railroad land from RF&P in order to build another Crystal City--a vast office-building development to be called Potomac Center. According to the agreement..., Fairchild will be allowed to build a highway bridge and cloverleaf from the railroad's property onto the Parkway at the current entrance to the Daingerfield Island sailing marina. In exchange for this privilege, the remaining piece of the marsh will be absorbed by the Park Service, the wetlands will be protected from further desecration."

In 1998, RF&P gave up access rights in exchange for release of covenants on their land in Arlington County.

No monies were available to buy out Smoot's interests. It was the expressed purpose and spirit behind the law that the Dyke Marsh area should be administered as wetland habitat for wildlife preservation. Congressman Dingell stated, "We expect that the Secretary will provide for the deposition of silt and waste from the dredging operations in such a way as to encourage the restoration of the marsh at the earliest possible moment."Between 1959 and 1973, SSGC dredged further into the marsh until the current configuration was reached (Fig. 2). In the meantime permits had been issued for dumping of "clean" materials into dredged areas. Hopper barges carried materials into open water areas while construction of a haul road with fill material accommodated truck dumping. Nearly one-half of the original wetland at DMP had been destroyed by dredging and filling. These activities ceased in 1972 when it was recognized that there was no effective management plan for the site. An additional 28 acres of contiguous marsh on the southern end (the Fairchild Tract) were acquired by the National Park Service in 1962. By January 1976 Potomac Sand and Gravel, the successor to SSGC, relinquished claims to dredging rights in the marsh, leaving unimpeded the management options open to the National Park Service.

Today the Haul Road is a soft surfaced trail, which provides access to the marsh. It is 3,600 feet long, impacts drainage patterns, and sustains occasional wash-overs during storm events. The trail is scenic and is used for hiking, access for fishing, bird-watching, and other forms of recreation.

## LEGISLATION PERTAINING TO DYKE MARSH PRESERVE

Federal legislation dealing with the purchase and governance of DMP is included in Appendix A.

## THE ABIOTIC OR NONLIVING ENVIRONMENT

### Geological and Historical Perspectives

The Belle Haven-DMP area and surrounding lands are located in the physiographic province known as the Atlantic Coastal Plain. The Coastal Plain of Virginia is underlain by stratified deposits of mud, sand, clay, gravel, and shells laid down by the ocean when it encroached onto the eastern edge of the continent over the past 100 million years. DMP lies on the Pleistocene Columbia Terrace; bedrocks in the vicinity are nearly 600 feet deep (Danton 1950).

Hunting Creek was once a major drainage stream, now markedly reduced, of the crystalline Piedmont through the unconsolidated sediments of the undifferentiated Cretaceous Potomac group and the stratified Pleistocene terraces of gravel, sand and clay. The creek was, therefore, a major source of the mineral deposits found beneath DMP.

In the past, velocity of this sediment-carrying creek slowed as it entered the quiet water of the estuary allowing deposition of the coarser sediment. This created a local rise in the gradient of the Potomac River, thus effectively reducing the major current to the point where the finer sediment dropped. This sequence provides a likely explanation for the evolution of DMP. Hunting Creek today plays a reduced role on DMP chiefly because its outflow has been severely altered by construction of the George Washington Memorial Parkway, ramps to and from the Capital Beltway, and channelization of its course. The sediment loads from increased urbanization have left a delta in the Hunting Creek embayment. This self-imposed barrier slows the discharge rate, allowing more deposition and reducing the discharge velocity into the main stream Potomac River. Recent boring probes in Hunting Creek Bay revealed areas of sand deposition on top of soft muds. Confining the creek's confluence with the Potomac is allowing deposition and preventing flushing.

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## Soils

From the geological evidence presented above, soils of the Coastal Plain came from mixed crystalline rocks and sediments. The soils derived from the unconsolidated sediments of the Coastal Plain adjacent to the Potomac estuary have sandy and clayey textures. The major soil group found in the Hunting Bay-Belle Haven-DMP watershed is the Mattapeake-Mattapex-Woodstown soil association. For DMP, the geological formations are probably of the Potomac group (Johnston 1964). On the area's eastern edge along the Potomac is the moderately well drained Metapeake type(Parsons et al. 1976).

Extensive boring in the marsh by the Smoot, Sand and Gravel Company in 1932-1934 and the U.S. Army Corps of Engineers in 1976 revealed the predominance of sand and gravel deposits with lenticular interlayed units of silt and clay. The sand and gravel deposits are found between -16 and -50 feet overlain by soft depositional muds. The sedimentary sequence found here reflects the changing conditions in depositional environment from one of swift moving waters, where only heavy sands and gravel would fall out, to one of slack water allowing finer silts and clays to settle.

The surface soils at DMP reflect to a major extent the source materials in the uplands to the west of the marsh, although some of the smaller materials could be derived from materials almost anywhere in the Potomac drainage. As the result of the Fairfax County Soil survey conducted in 1955, it can be stated with reasonable confidence that these soils are Coastal Plain loamy and gravelly sediments belonging primarily to the Beltsville and Matapeak soil associations.

Preliminary tests of the outer dike structures, which have existed since the early 1800s, indicate that internally they contain no rock or other material foreign to the marsh area. It appears that the dikes were constructed from immediately available materials. Cobblestones on the surface of one dike are typical and similar to rock found in the nearby Potomac basin.

As part of the DMP Restoration Project, soil samples were collected at two sites in the summer of 1976 (National Park Service, 1976; Table 1). For the most part, effects of any or all of these elements and compounds DMP are presently poorly known.

## Hydrology

According to Carter et al. (1994) the tidal Potomac River near DMP "... is fresh (salinity < 0.5 $mgL^{-1}$) except during periods of low discharge. The average annual flow is 323 $m^3 s^{-1}$. The mean tidal range in the upper tidal river is 0.6 m to 0.9 m and in the lower tidal river 0.5 to 0.6 m.... The waters of Dyke Marsh are dominated by the Potomac River with some, mostly historical, input from Hunting Creek. Also the marsh is bathed by daily Potomac tidal cycles which have a normal 3-foot flux. Flow rates of fresh water contributed by upstream areas of the Potomac go past the marsh at an average volume of 11,000 cubic feet per second. With few exceptions from major summer storm events, the highest flows can be expected in March and April following snow melts on upstream portions of the Potomac River. Even during high flow periods the water level is seldom raised one to two feet higher than normal. These flows generally occur before marsh vegetation becomes established in the spring.

Two islands with the remaining remnant dikes protect the main marsh from any downriver flows which might be directed towards the marsh. However the combined effects of southerly to easterly winds, incoming tides, or both can cause temporary

TABLE 1. Analysis of soil samples in Dyke Marsh Preserve (National Park Service, 1976). Given are mean values in ppm.

| | In Marsh | In Demonstration Site |
|---|---|---|
| Nutrients: | | |
| organic carbon | 4.48 | 3.12 |
| ammonium | 51 | 54 |
| total phosphorus | 35 | 517 |
| Metals: | | |
| arsenic | 0.34 | 0.44 |
| lead | 3.69 | 4.28 |
| manganese | 53.25 | 186 |
| mercury | 0.014 | 0.006 |
| molybdenum | 0.03 | 0.05 |
| cadmium | 0.23 | 0.35 |
| chromium | 0.30 | 0.86 |
| copper | 6.58 | 7.15 |
| iron | 119.50 | 243.50 |
| nickel | 1.67 | 2.19 |
| zinc | 24.50 | 34.75 |
| No PCBs | | |
| Chlorinated hydrocarbons (DDE) | 0.04 | 0.068 |

periods of high water which may completely inundate the marsh. It should be noted that damage is most severe as waters begin to flow over the marsh, not when the marsh is covered. Thus, DMP is entirely within the annual flood plain of the Potomac estuary. To date the significant effect of water action, may be the result of wind and boat-created waves, and scour from major flood events, which lap at the steep-sided shorelines left from previous dredging. These shorelines are gradually being eroded back in several areas, and vegetation is impacted due to loss of soil cover.

The erosive potential of the tidal cycle toward the creation of a tidal marsh drainage pattern can actually be gleaned from recorded history in this area. After the digging and filling behind the dikes in the early 1800s, no drainage guts occurred through the embankments aside from the two natural channels at the inner marsh. The point of significance here is that tidal action naturally tends toward the evolution of tidal guts and typically a natural dynamic equilibrium exists between depositional land forming activity and the erosive action of tidal movements. The erosive action at DMP would persist until the energy differential caused by shoreline heights and river bottom depths is dissipated. There are no persistent freshwater streams flowing through the marsh, other than the Potomac River. Dyke Marsh Creek and Hog Island Gut do serve to conduct drainage from the high lands west of the marsh."

In an unpublished report Harper and Heliotis (1992) developed a hydrological model for DMP. Among their findings was the fact that dye tests taken in various parts of the marsh confirmed the high flushing rate in each tidal cycle. The main marsh was primarily watered by the Hog Island Gut from the south and secondarily from the north by the inlet south of the Haul Road. This demonstrable flushing action is significant to nutrient flow and export from DMP.

### Water Quality

Water quality at DMP is dominated by the man-related effluent from upstream which includes high levels of persistent turbidity, excessive nutrients, and some loads of heavy metals or other toxic chemicals. Turbidity has undoubtedly been the critical factor in the loss of submerged vegetation in the upper Potomac estuary. In terms of the food chain, the loss of this vegetation has led to the depletion of dependent biota which is the food base for wildlife such as diving ducks and fish. In the past nutrient loads have become heavy enough for the surficial blue green algae populations to explode and then decline. This dying biomass supports increased bacterial populations which utilize the dissolved oxygen supply for their respiration and deprive the fish and other biota of the same life-sustaining element. It is critical to the future of DMP, as well as to the entire Potomac Estuary, that both turbidity and nutrient loading be decreased.

A decrease in one of these is not enough and might even be more harmful. For example, a decrease in turbidity along with continued high nutrient content eventually would lead only to the aforementioned condition of low dissolved oxygen or eutrophication. Preliminary studies by Horace V. Wester (pers. comm.) suggested free chlorine as one of the primary pollutants specifically affecting aquatic vegetation. More efforts are needed to define the effects of this and other pollutants as a way of predicting their impact on wetland vegetation. The decrease of some vegetation such as *Zizania aquatica* (wild rice) and even the pest water chestnut can be attributed to water pollution conditions preventing vigorous growth. In the meantime, qualitative and quantitative data serve as a frame of reference as to the status of pollutants in the environment.

Data collected from the Blue Plains Sewage Station were indicative of generally poor water quality. During the period 1962-1971, the surface mean chloride content near Blue Plains averaged 0.02 ppt, water temperatures ranged from 1° to -30.5°C, alkalinity as expressed by $CaC0_3$, between 23-142 mg/L and pH between 6.8-8.3. However, DO (dissolved oxygen) was low (12%), BOD reached a maximum of 0.5 or 14.1 mg/L, and fecal coliform density ranged near 1 million MPN/100 mL. Typical levels of key ingredients indicate periodic high levels, suggesting that when high nutrient loads coincide with warm water temperature and ample sunlight algal populations will increase to bloom proportions, thus leading to eutrophication (National Park Service, 1976).

In 1979, water quality in the river including the DMP region was considered to be in the good range--pH 8.1-8.4; dissolved oxygen 6.0-7.9 mg/L; suspended solids 25-80 mg/L; total organic carbon 5-20 mg/L; nitrate nitrogen 0.21-0.60 mg/L; total phosphorus 0.05-0.25 mg/L; chlorophyll a 25-49 μg/L; fecal coliform bacteria =201-500 (U.S. Army Corps of Engineers, 1988).

More specifically, average summer conditions in Hunting Creek embayment for 1985 were-- pH=6.1 (range for region=7.0-8.1); dissolved oxygen =7.1 (7.4-8.6) mg/L; total suspended solids=39 (9-14) mg/L; total organic carbon=8.0 (2.4-3.3) mg/L; nitrate nitrogen=0.19 (0.73-1.94) mg/L; total phosphorus=0.13 (0.09-0.10) mg/L;

chlorophyll a=10 (7-13) µg/L; fecal coliform bacteria =2,306 (20-8,590). These averages resulted in an index score of 4.25 which put the embayment in the "GOOD" range of water quality classification. However, both the pH and bacteria counts were considered to be standard violations.

In a report, "1984 Dyke Marsh Water Quality Data," from the Metropolitan Washington Council of Governments, results of sample analyses indicated that (1) throughout the summer months dissolved oxygen remained close to saturation, (2) total suspended solids were generally less in DMP than in the main Potomac River channel, (3) total phosphorus loads decreased, (4) nitrogen decreased, and that (5) chlorophyll a reached a peak in July and decreased thereafter. As far as the suspended solids are concerned, the data support the idea that the presence of submersed aquatic vegetation (SAV) promotes settling of sediments and improved water quality.

Clarity is another important water quality consideration which has a direct impact on aquatic ecosystems. High turbidity, measured by total suspended solids, results in reduced light penetration into the water column and therefore, reduced light availability for aquatic life. Water quality in the embayments of the Potomac River tends to be better than in the mainstream. Several factors contribute to this phenomenon, one of which is the quick settling rate of sediments to the bottom because of the slower, reduced flow conditions typical of embayments. Another factor is the assimilation of particles by aquatic vegetation as a nutrient source. In addition, trapping the particles from the water column prevents them from being carried away by the current to other areas.

These data on water quality need to be updated to assess possible future effects on the DMP area.

### Drainage Patterns

Drainage patterns within DMP are controlled by the overall influence of the Potomac and the tidal flow. However, as part of the peculiarity of the dredged and formerly diked marsh, minor drainage flows generally away from the outer edges of the emergent marsh toward the two major tidal creeks. This is due to human removal of large portions of the marsh, leaving the earlier highest portions of the marsh at its extremity.

The Hunting Creek Estuary has a drainage basin of 0.79 $mi.^2$, the channel length is 1.48 mi., and severe sedimentation has occurred, leaving a bed of silt, clay and rich organic material (Parsons et al., 1976).

Conducting field work in the late spring and summer of 1963 on the Wrecked Recorder Creek (now largely destroyed), Myrick and Leopold reported that "...the southern of the three estuarine channels carries away nearly all the surface runoff originating in the high ground adjacent to the marsh. The water exchanged with the Potomac estuary is here quite fresh (not salty).... Shortly thereafter, dredging operations for commercial gravel production destroyed the channel system.... For Wrecked Recorder Creek, water depths generally increased as a function of distance from the channel origin, from about 3 feet below level of the marsh to about 5 feet. Width of the channel increased from 18 to 134 feet.... Velocity, and thus discharge, at a given stage was dependent both on the maximum stage attained by the particular tidal cycle and the range of stage in the tidal cycle.... The estuarine channel differs from a terrestrial one in that discharge at any section in an estuary varies depending on how the flow shaped the entire length of the channel between the point in question and the main body of tidal water. The result is that a tidal channel changes more rapidly in width and less rapidly in depth as discharge changes downstream than does a terrestrial channel.... In tidal channels, zero discharge occurs twice in every tidal cycle, and thus there are also two occurrences of high discharge in each cycle."

## THE BIOLOGICAL ENVIRONMENT

### Some Historical Reports

The oldest known plant identifications were those of Waldo McAtee (1918, p. 96) who described the flora of Hunting Creek: "Hunting Creek, just below Alexandria, has a very interesting flora. It is filled with aquatic vegetation, among which *Potamogeton robbinsi* and *Utricularia macrorhiza* are its exclusive possessions in this vicinity. The peculiar marsh plants are *Eleocharis flaccida*, *Carex gracillima*, *Plantago cordata* (also found opposite Alexandria) and *Eupatorium cannabinum*; and mud flats, *Isoetes riparia* and *Micranthemum micranthemoides*. Other interesting species occurring here are *Alopecurus geniculatus*, *Pedicularis lanceolata* and *Galium asprellum*." For DMP, he continues "The marsh is a beautiful sight during the flowering season of the abundant introduced *Iris pseudoacorus*. In this marsh only has been collected the fragrant ladies tresses (*Ibidium odoratum*)."

### Submersed Aquatic Vegetation

SAV has long been a subject of controversy in the Potomac River near Washington. The debate has largely centered around the benefits and negative effects of the SAV. SAV is rooted in the bottom and typically grows in water six feet or less. Generally, SAV, on the one hand, provides shelter and food for a variety of wildlife, reoxygenates the water column, absorbs nutrients, and reduces erosion. It has been estimated that SAV supplies nearly one-half of the summer diet of most waterfowl species (Anonymous, Army Corps of Engineers 1988). On the other hand, the presence of some SAV tends to shade out other aquatic plants, reduce the diversity of aquatic flora and fauna, and clog waterways making them less accessible to swimmers and boaters (Steward et al. 1984).

Virginia Carter, Nancy Rybicki, and their colleagues at the U.S. Geological Survey have published several pertinent papers on the biology and distribution of SAV along the Potomac River in recent years. Prior to the 1930s, species reported from the tidal Potomac River included *Vallisneria americana* Michx., *Ceratophyllum demersum* L., *Najas flexilis* (Wild.) Rostk. and Schmidt, *Elodea canadensis* (Michx.) Planch., and *Potamogeton crispus* L. (Carter et al. 1994). In the late 1930s, these plants largely or entirely disappeared. In 1983 SAV began returning to the freshwater portion of the Potomac River. In 1986 the percent cover of SAV in DMP was 70-100.

A 1978-81 survey of submersed aquatic macrophytes in the tidal Potomac River showed that there were virtually no plants in the freshwater tidal river between Chain Bridge and Quantico, Virginia (Carter and Rybicki, 1986). Carter and Haramis (1980) related the loss of SAV to the decline of waterfowl in the Potomac River. From a systematic survey conducted in 1978 and 1979, they concluded: "The limited distribution of submersed aquatic vegetation is associated with a decline in use of the tidal Potomac by wintering diving ducks, particularly pochards [diving ducks]. These waterfowl have either shifted their food consumption to a higher percentage of animal foods or moved to other areas. Very few diving ducks are found in the tidal river; larger concentrations are found in the transition zone and lower estuary where small mollusks and submersed aquatic vegetation are more abundant. It is possible that degraded wintering habitats have indirectly reduced winter survival of waterfowl and may have been one factor causing continental waterfowl declines in this century."

Richard Hammerschlag (1984, 1985) reported on studies relating to the physiology of *Hydrilla* at DMP with special reference to water quality. These studies followed an invasion of *Hydrilla* in the Potomac estuary since 1981. He found that (a) a principal contribution to the intensive growth of *Hydrilla* was unusually warm April water temperatures, (b) the effects of *Hydrilla* on dissolved oxygen levels were important to the biological stability of the estuary, (c) *Hydrilla* reduced suspended particles in the water column, (d) *Hydrilla* mass increased visibility in the water column, (e) growth of *Hydrilla* reduced turbidity through reduction of particles in the water column, (f) *Hydrilla* did not appreciably affect the overall level of solutes, and (g) higher nutrient levels were recorded in the spring and fall with depressed levels occurring during the summer season. Thus, a positive effect of SAV would be to utilize and thus remove nutrients from the water column and hydrosoil during the growing season. One result of this action is that SAV could be an effective nutrient buffer in the estuary by serving as a nutrient sink during the summer growing season and serve as a releasing mechanism for nutrients into the water column in the fall.

Carter and Rybicki (1986) also reported that "In 1983, 12 species of submersed aquatic macrophytes were found in the tidal river. Population increases were dramatic: by fall 1985, plants had colonized all shallow areas between Alexandria and Gunston Cove, Virginia. *Hydrilla verticillata* dominated in Dyke Marsh-Hunting Creek and Swan Creek. Most other areas contained a variable mixture of *Heteranthera dubia, Myriophyllum spicatum, Ceratophyllum demersum, Vallisneria americana, Najas guadalupensis*, and *Hydrilla verticillata*. No plants were found along the main river or in tidal embayments in the reach between Gunston Cove and Quantico, Virginia. Total dry weight collected in the upper tidal river in fall 1985 was 14.5 times that of spring 1985, and four times that of fall 1984.

"Thirteen species were reported from the tidal river during 1983-1989. The most widespread species from 1983 to 1989 were *Hydrilla verticillata, V. americana, Myriophyllum spicatum, C. demersum,* and *Heteranthera dubia.* The dominant species currently in terms of biomass and cover are *H. verticillata, M. spicatum*, and *V. americana. H. verticillata* and *M. spicatum* are exotic species and are often considered nuisance plants because they outcompete native species."

In another report, Carter et al. (1985) provided additional information on the distribution and abundance of SAV in the tidal Potomac River and Transition Zone of the Potomac estuary, Maryland, Virginia, and the District of Columbia. They noted the species distribution at several DMP sampling transects in 1984--Spring, *Hydrilla verticillata* (Hydrilla); fall, *Ceratophyllum demersum* (coontail), Hydrilla, *Nitella flexilis* (muskgrass), *Myriophyllum spicatum* (Eurasian watermilfoil). In biomass ($g/m^2$)--Spring, trace-27; fall, 691. Overall species diversity was low, 1-2, especially when compared with transects downriver from Dyke (>4). The substrates were clay and silt.

To understand the effects of weather (especially wind) and water quality on SAV, Carter et al. (1994) analyzed the results of a number of tests. In the Potomac River at DMP, growing-season Secchi depths were <0.60 m. before resurgence of macrophytes. Following the resurgence of macrophytes in 1983, they found "... a growing-season Secchi depth of 0.86 m, total suspended solids of 17.7 mg/L, chlorophyll a concentrations of 15.2 μg/L, significantly higher than average percent available sunshine, and significantly lower than average wind speed. From 1983 to 1989, mean seasonal Secchi depths <0.65 m were associated with decrease in plant coverage and mean seasonal Secchi depths >0.65 were associated with increases in plant coverage." They concluded that Secchi depth is highly correlated with plant growth in the upper tidal river, and that wind speed is an important influence on plant growth.

By 1996, various reports indicated increased coverage by SAV. According to the Council on Environmental Quality (1996), "between the Woodrow Wilson Bridge and Indian Head, vegetation is beginning to return to sites along the George Washington Parkway (such as DMP) for the first time since 1989." The Environmental Quality Advisory Council for Fairfax County (EQAC) annual report on the environment in 1996 noted that "Vegetation is increasing between Roosevelt Island and the Woodrow Wilson Bridge. In this reach most beds are dominated by Hydrilla but several large beds, such as one along Reagan National Airport, are dominated by wild celery (*Vallisneria americana*). Water stargrass (*Heteranthera dubia*) dominates a bed on the shoal just south of National Airport.

Between the Woodrow Wilson Bridge and Indian Head, vegetation is beginning to return to sites along the George Washington Parkway (such as DMP) for the first time since 1989. Vegetation continues to grow in embayments on the Maryland side, but not nearly to the extent it did in the past. Wild celery or hydrilla are the dominant species here."

## Emergent Vegetation

In an early preliminary observation of marsh plants and moist-soil herbs, Francis M. Uhler (1963) listed 49 plant species. He continued, "A study made during the growing season will undoubtedly add many other marsh and swamp plants as frosts had caused the vegetation to disintegrate before these observations were made. A few drifting plants of sago pondweed (*Potamogeton pectinatus*) and wild celery (*Vallisneria spiralis*) in the open water at the north end of the DMP indicated that some of these important, submerged, seed plants still exist in sections where the water is clear enough to permit the necessary penetration of sunlight." Of the 49 species, Uhler considered 14 to be good to excellent waterfowl foods.

Similarly in 1963, Myrick and Leopold reported general observations of the vegetation: "The dominant vegetation [of the marsh] consists of cattails, *Typha latifolia*, and probably also T. *angustifolia*. [a note appended to the paper indicates that the latter species is the dominant, as determined by Uhler.] Both species are to be expected in localities such as this, but *T. angustifolia* is in general dominant in areas of salty water. The basal part of some stands of *Typha* is whitened in spring, probably showing the limit of tide. Another plant common to the area is the arrow arum, *Peltandra virginica*. Some of the plants are unusually luxuriant and might be taken for the yellow water lily, *Nuphar advena*, especially where partly submerged. The trees growing in some areas slightly higher in elevation than average marsh surface include green ash, *Fraxinus lanceolata* [=*pennsylvanica*], which is a common tree in such places in the tidewater region. The willows are probably *Salix nigra*, common along the Potomac in the Washington area."

As a result of an intensive and extensive survey of the DMP flora, Xu (1991) provided a list of 373 species (see Xu 1991, for a complete list of species found). Most of the species are common species of the local flora. Of these, 60 species (16%) were listed as obligate wetland species.

Xu also initiated eight east-to-west permanent transects across the Preserve with sampling points on marshland at (normally) 20-m intervals. During the fall of 1991 both wooded and herbaceous (open marsh) sites were sampled, determining the species present, individual species counts, coverage, height, and circumference, as well as noting surrounding flora. His findings indicated, among other things, that the natural wave action of water in the river is dredging the marsh away. The establishment of the permanent transects would assist in monitoring such effects in the future.

The results of a continued transect survey at Hog Island gut, although probably not reflecting vegetation of the entire marsh, by Lindholm (1992) indicated that:

(1) greater than 98% of the open marsh consisted of the eight species (from highest to lowest frequency of percent of quadrats with at least one specimen): *Peltandra*, *Typha*, *Impatiens*, *Nuphar*, *Cuscuta*, *Acorus*, *Leersia*, and *Scirpus*. Thus, species richness is generally low in the open marsh. The open marsh points (n=53) sampled result in a Shannon-Wiener diversity index of 1.668. Density in the open marsh was: *Impatiens capensis*, 41.2%; *Peltandra virginica*, 20.8%; *Acorus calamus*, 12.8%; *Typha* spp., 13.0%; *Nuphar luteum*, 5.5%; *Leersia* sp., 3.5%; *Scirpus fluviatilis*, 1.2%.

(2) average cover per species: *Peltandra*, 29.9%; *Impatiens*, 20.8%; *Nuphar*, 20.3%; *Typha* spp., 17.6%; *Acorus*, 4.9%; *Cuscuta gronvii*, 2.4%;*Leersia*, 0.9%.

(3) species density (average number /$m^2$ ) in decreasing order: *Impatiens*, *Acorus*, *Peltandra*, *Typha*, *Nuphar*, *Leersia*, *Scirpus*.

(4) average species heights in meters, in decreasing order: *Typha*, *Scirpus*, *Acorus*, *Impatiens*, *Leersia*, *Nuphar*, *Peltandra*.

(5) it appears that *I. capensis* and *P. virginica* are among the dominant species at this time of year [summer] throughout the open marsh, with *A. calamus*, *Typha* spp., and *N. luteun* sharing cover (and hence dominance as one moves from north to south in the open marsh.

Little is presently known about the composition of the botanical community within the Belle Haven recreation site. Additional inventory is needed to establish a baseline database for this area.

### Changes in Vegetation

Historical data indicate that significant changes have occurred in the vegetation of DMP in recent decades. Some plant species, such as the heart-leaf plantain (*Plantago cordata*), have become extinct (Kelso et al., 1993). The species was recorded as common in Alexandria and DMP area since the 1870s according to available collections of this species in the Smithsonian Institution (US Herbarium). Existence of this species in DMP until 1918 is revealed in those collections. But since 1918, no records of this species have been found in DMP and the adjacent area. Curators of the Smithsonian and other institutions have explored the DMP several times in recent decades, but no one was able to re-collect this species. Perhaps other species have also disappeared.

Among the changes in vegetative patterns are those reported by Kelso et al. (1993). Many clumps of Spatter Dock (*Nuphar luteum*) do not appear in the 1970s aerial photos, but are now obvious, in Hunting Bay near the outlet of Hunting Creek. In the marsh, the same species has filled a lot more waterways, and occupies larger area than in 1970s. Exotic species continue to be controversial, some apparently invading natural communities. The Common Reed (*Phragmites australis*) was observed without a clear stand in 1970s, but now forms two large stands in the marsh. One of these is on artificial substrate at the Haul Road, and the other in an area considered to be early successional. Sweetflag (*Acorus calamus*) has taken over some areas that were occupied by Arrow Arum (*Peltandra virginica*) in recent decades according to their community size. Some of these changes are not so much "invasions" by other species as changes in hydrology and sedimentation. Even so, some vines are invading the swamp forest.

Studies show that since the 1970s changes in vegetation in DMP demonstrate the dynamics found in an active marsh ecosystem. The variance of information found in studies conducted by Thomas (1976) and Xu (1991) indicates the strong need for an active monitoring and research program to monitor changes taking place within the marsh.

## Plant Communities

DMP can be divided into three major zones or plant communities: the marsh proper (tidal freshwater marsh), the floodplain forest, and the swamp forest. Parts of the marsh proper, which comprises about 35 percent of the area, are partly underwater except at low tide. The floodplain and swamp forest are about 4 feet above mean high tide and are not inundated during normal tidal cycles. The tide, however, does carve deep tidal guts into the marsh. Occasionally, strong easterly winds coupled with an incoming tide can flood the marsh for several hours.

The marsh proper is about one-half covered with cattails, with other common marsh plants such as arrow arum, sweetflag, and spatterdock also prevalent.

Parsons et al.(1976) reported that the tidal freshwater marsh contained common wild rice, cattail, yellow pond lily, pickerel weed, many sedges. "The plant community can be divided into two zones. Very tall herbs, such as cattails, wild rice and polygonums, are found on the shore. In comparison, much shorter vegetation including pickerel weed, yellow pond lily and tuckahoe grow right along the river. The marshland of this environment, known as Dyke Marsh, is not dominated by any one plant, although the most abundant species are the cattails, with pickerel weed-arrow arum second in abundance and yellow pond lily third."

The floodplain forest is separated from the marsh proper by a border of shrubs including swamp rose, buttonbush, and alder. Elm, sweetgum, red and silver maple, and box elder are among the dominant trees. The swamp forest is a depressed area possibly formed by an old river bed. In this forest are found green and pumpkin ash, black willow, spicebush, arrow wood, and many other trees.

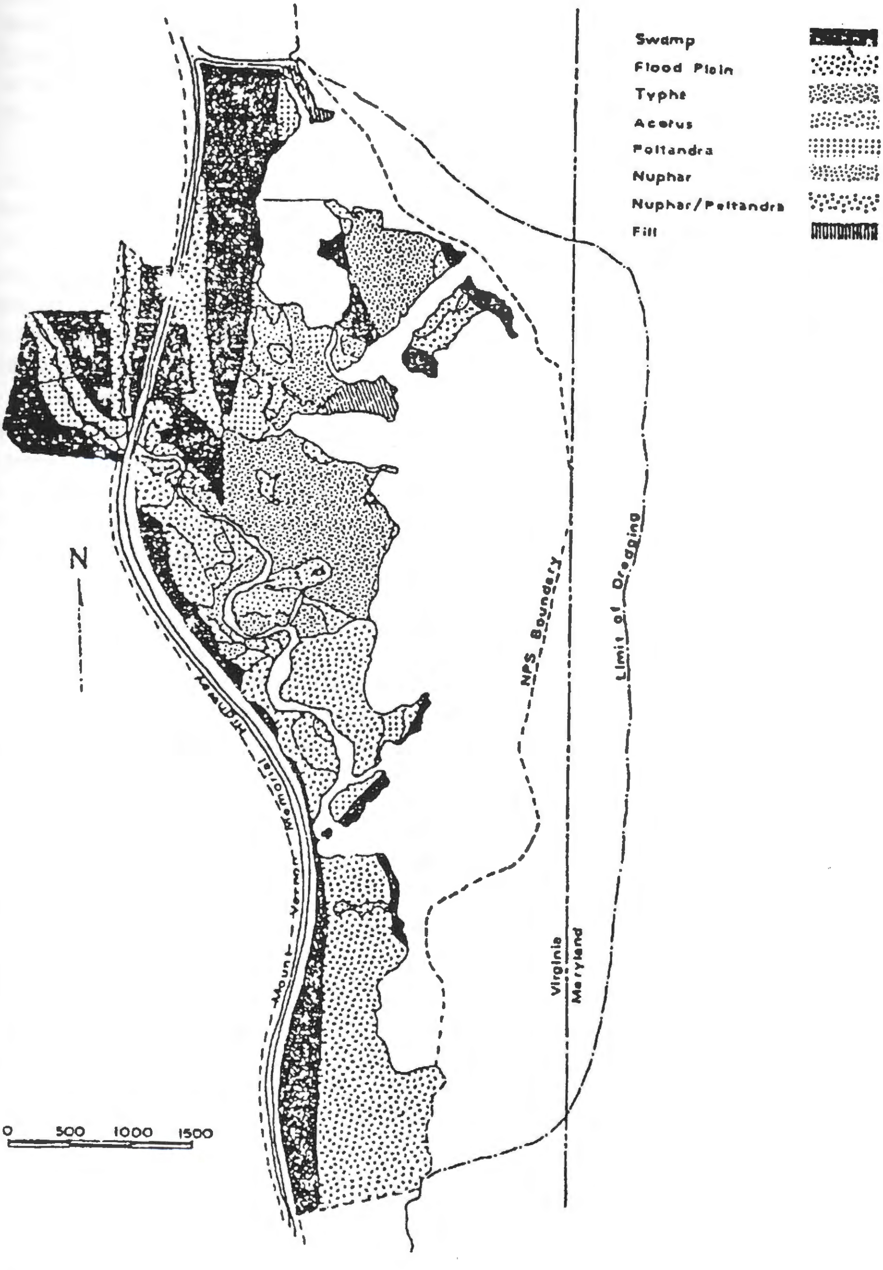


FIGURE 3. Vegetation map of Dyke Marsh Preserve.

TABLE 2. Vegetation types from transects in Dyke Marsh (Xu, 1991)

| Vegetation Types | Acres | Percent |
|---|---|---|
| Dyke Marsh Proper | | |
| Floodplain forest | 89 | 36 |
| Secondary vegetation | 13 | 5 |
| Swamp forest | 47 | 19 |
| *Nuphar-Peltandra* | 22 | 9 |
| *Typha* (mixed) | 49 | 19.5 |
| Mixed non-*Typha* | 28 | 11 |
| Wild rice (mixed) | 0.8 | 0.3 |
| *Phragmites* (pure) | 0.5 | 0.2 |
| Total | 249.3 | 100 |
| Hunting Bay area | | |
| Secondary vegetation | 51 | 82 |
| *Typha* (mixed) | 5 | 8 |
| Floodplain forest | 6 | 10 |
| Total | 62 | 100 |

The general vegetation composition of DMP (Fig. 3) was delineated by Thomas (1976) as follows:

DMP as a whole--

1. *Nuphar* (spatterdock) zone 1%
2. *Nuphar-Peltandra* (spatterdock and arrow-arum) mixture 5%
3. *Peltandra* (arrow-arum) zone 8%
4. *Acorus* (sweetflag) zone 4%
5. *Typha* (cattail) zone 20%
6. Swamp forest zone 30%
7. Floodplain forest zone 32%

The marsh proper--

1. *Nuphar* zone 2%
2. *Nuphar-Peltandra* 12%
3. *Peltandra* zone 21 %
4. *Acorus* zone 12%
5. *Typha* zone 52%

The Swamp forest zone contained Pumpkin ash (*Fraxinus tomentosa*), Green ash (*F. pennsylvanica*), Black willow (*Salix nigra*), American elder, swamp haw, black gum, and others.

The Floodplain forest contained American elm, White mulberry, cottonwood, sweetgum, black cherry, red and silver maple, willow oak, American Beech.

Xu's transect studies (1991) provided a classification of plant communities and the estimated acreage of each (Table 2).

In 1976, L. K. Thomas, Jr., as part of a team for an environmental assessment of DMP, reported a preliminary delineation of the DMP vegetation. In that report, 289 acres of the marsh vegetation and 87 acres of the swamp forest were mapped. Comparing numbers in 1976 with the ones in Xu's 1991 report, it appears that some 40 acres of marsh and swamp forest each were lost in the 15-yr. period area, while the floodplain forest remained virtually unchanged.

Within the marsh, *Nuphar* (spatter dock) has filled more waterways and increased in acreage since 1976. This may mean that the sediment deposit has increased in the marsh in the last two decades. The *Acorus-Bidens* mixture may have taken over some of the areas previously identified as the *Peltandra* territory. It is evident that in the marsh at the southernmost of the parkland *Acorus* grows with *Peltandra* but the former species shades the latter one. The two species occur in similar water levels and grow in the same season. The *Typha* community remains the climax vegetation, relatively stable in its community size.

From an unpublished report of a morning hike on 20 May 1991 along the Haul Road. "The area had a high diversity of exotic plant species including: *Lonicera japonica*, *Celastrus orbiculatus*, *Alliaria petiolata*, *Ampelopsis brevipedunculata*, and *Rosa multiflora*. Marshes that could be observed from the trail appeared to be free of *Phragmites* indicating potential high quality. A boardwalk and trail crosses a stretch of nutrient-rich marsh containing *Numphar luteum*, *Peltandra virginica*, *Acorus calamus* and other species, and a *Liquidambar styraciflua-Fraxinus pennsylvanica* swamp. Habitat for the rare plant *Carex decomposita* was noted in areas both north and south of the parking lot."

It must be emphasized that vegetation "changes" in general are not always real but may be artifacts of different sampling methods, different definitions of some zones, and differences in location of the outer bounds of the area studied.

These studies *en toto* demonstrate the dynamics of the marsh ecosystem and possible environmental impacts on the ecosystem, all of which suggest the need of setting up a long-term monitoring program so that biodiversity changes of this ecosystem in the future can be identified based on adequate quantification.

### Rare Plant Species

From searches of herbarium and museum specimens and literature sources, a Natural Heritage Inventory in June 1991 identified rare plant species in the DMP area: rough avena (*Geum laciniatum*), river bulrush (*Scirpus fluviatilis*), the Virginia mallow (*Sida hermaphrodita*), and epiphytic sedge (*Carex decomposita*).

Xu (1991) reported the presence of American plum (*Prunus americana*) in the marsh, great burrweed (*Sparganium eurycarpum*), and small leaf elm (*Ulmus carpinifolia*).

## INVERTEBRATES

To date, complete sampling of any invertebrate taxa in DMP has not been carried out. The following discussion presents what is currently known from scattered reports, chiefly those of Parsons et al. (1976) and the U.S. Army Corps of Engineers (1988).

### Aquatic Communities

The benthic community in the Potomac River plays an important role in the aquatic food web. Some species are important because of their commercial and recreational value. Although the precise composition of the benthic community of the River and DMP waters is not known, reports from the Potomac River and the Belle Haven area suggest the presence of a variety of Annelida (segmented worms), Mollusca (bivalves), aquatic insects, Crustacea isopods, amphipods, and others)(Parsons et al. 1976; U. S. Army Corps of Engineers 1988).

### Ectoprocta (moss animals)

Belle Haven estuary at DMP
Ectoprocta--*Fredericella sultana*

### Annelida

Bottom samples collected at DMP reveal a benthic fauna characteristic of polluted waters, with tubifex worms and chironomid flies predominating.

Belle Haven Estuary at DMP
Oligochaeta
Hirudinea (leeches)

### Mollusca

According to observations of Dr. Francis M. Uhler in 1963, "In addition to the abundant, viviparous Japanese snail (*Viviparous japonicus*), several native snails and clams, including *Goniobasis virginica*, *Helisoma* sp., *Musculium* sp., and larger thin-shelled clams, were common in the shallow waters. These compose useful resources of invertebrate foods for aquatic wildlife." Gerberich (1984) reported that the endangered *Lasmigona subviridis* (Green floater) and the threatened *Elimia virginica* (Piedmont elimia) have been taken along the Potomac River near DMP.Beetle (1973) provided a checklist of 35 species of the land and freshwater mollusks of Virginia known from Fairfax County (Appendix B). Some of these species have been found in DMP and the surrounding areas.

### Arthropoda

As mentioned above, chironomids are characteristic in the benthic fauna.

Odonata--one record for the rare clubtail dragonfly (*Gomphus fraternus*) (Natural Heritage Inventory). From the Belle Haven estuary, *Perithemis* sp. (Parsons et al. 1976).

Crustaceans--Historic records gleaned from museum specimens and the literature show that rare amphipods (*Stygobromus*) were once collected nearby: Alexandria, *S. phreaticus*; Belle Haven Golf Course, *S. tenuis* (Natural Heritage Inventory). Dr. Uhler (1963) also reported "a good supply of crayfish."

### Hexapoda (insects)

In the past the DMP area has produced several additions to the craneflies of the region, and has yielded the only specimen so far obtained of the remarkable horsefly, *Merycomyia*. The large hymenopteran, *Pepsis elegans*, related to the western tarantula hawks, was seen only at DMP and Mount Vernon in a broad-scale survey of the region by McAtee (1918). From the Belle Haven estuary, Hemiptera (Gelastocoridae, toad bugs) and Diptera (Chironomidae, midges) have been reported.

In 1997 Edward M. Barrows of Georgetown University began a survey of hexapod habitats, richness, and relationships on the DMP. That continuing long-term survey will provide lists of species and will provide a large baseline data set which can be used in forthcoming years to assess the effects of environmental changes and other factors on this Preserve. Using floating Malaise traps that move up and down with the tide in an open marsh, Dr. Barrows and his students will continue to collect specimens throughout the year. Traps will be set in the low forest, open marsh, and forest-marsh ecotone.

At least 6,000 hexapod species may be found in this Preserve. Appendix C provides preliminary lists of the orders (32) and number of species (292) by taxonomic order that have been found by the end of 1998.

Foods of these hexapod orders are also found in Appendix C. As expected, insect foods vary from detritus, bacteria and fungi, plant parts to carnivores on other insects and vertebrates. This information can be used in developing specific food chains and food webs of DMP.

## VERTEBRATES

### Fish

A recent report from the U.S. Army Corps of Engineers (1988) noted that "The study area supports a moderate amount of sport fishing. Sport fishing occurs most frequently in the tributaries where the catch includes yellow perch, white perch, catfish, largemouth bass, sunfish, crappie and chain pickerel. As a result of improved water quality conditions and the resurgence of SAV, the upper tidal river has been attracting more recreational fishing with largemouth bass, striped bass, yellow perch, and catfish being the most frequently sought after species."

Several anadromous fish utilize the Potomac River for spawning and care must be exercised that activities in DMP and the River should be scheduled as to minimize impact on these fish. Examples of such fish are Alewife, Blueback Herring, White Perch, American Shad, Striped Bass, and potentially the Atlantic Sturgeon.

Although no complete survey of fishes has been carried out in DMP or specifically in the contiguous Potomac River, occasional observations and reports as well as distribution maps from the published literature strongly indicate the presence of 62 species see Appendix D). A preliminary analysis of the residency habits of these species shows the following categories: 7 anadromous, 1 catadromous, 7 rare or probably extirpated, and at least 20 permanent residents. From what is known about their feeding habits, 5 are filter-feeders, 4 are omnivores, and 45 are predators (on arthropods, small invertebrates, fish).

Future studies should elucidate in greater detail the roles of specific fish species on the DMP ecosystem.

### Amphibians and Reptiles

Although making no specific mention to the DMP area, in an early "List of batrachians and reptiles of the District of Columbia and vicinity" Hay (1902) included several species found at Mount Vernon just south of DMP. Species included were Marbled salamander, Scaly salamander, Slimy salamander, Newt, Swamp treefrog, Brown-back lizard, Ground snake, Ring-necked snake, Red-bellied snake, and DeKay's snake. Most of these have not been found in recent years.

Observations by Walter Bulmer (1996-99) and his students in DMP have revealed the presence of the species listed in Appendix E. Only 9 species of amphibians, 7

TABLE 3 -The numbers of amphibian and reptile species found in principal habitats of Dyke Marsh Preserve

| | Forest Ponds | Marsh | Woodland[1] |
|---|---|---|---|
| Salamanders | 1 | | 1 |
| Frogs and Toads | | 5 | 2 |
| Turtles | | 6 | 1 |
| Lizards | | | 2 |
| Snakes | | 1 | 2 |

[1] a combination of swamp and floodplain forests

turtles, 2 lizards, and 3 snakes were found during this time period. Habitats utilized by these species are given in Table 3.

Amphibians and reptiles listed in previous reports (Abbott 1976, Parsons et al. 1976) but not found currently are also given in Appendix E. The Parsons report included areas outside of DMP, such as Dogue Creek.

## Birds

Birds comprise an obvious faunal element of DMP, represented by many resident and migratory species. Because of birds' conspicuous attribute and the increasing numbers of bird-watchers at the marsh and contiguous areas, more data are available for birds than any other animal group.

A summary of historical records indicates a long-time interest in the bird life of DMP and surrounding areas. Famous ornithologists and naturalists observed birds in the region between 1895 and 1925: Harry C. Oberholser, Alexander Wetmore, W. L. McAtee, Ludlow Griscom, E. A. Preble, May Thacher Cooke, R. W. Shufeldt, Francis Harper, Albert K. Fisher, and Frederick C. Lincoln. Their reports are found chiefly in *Bird-Lore*, *Wilson Bulletin*, and *Auk*. The earliest bird record for the DMP area is mention of "...king fishers which now build their nests in its rugged sides...," and "...I bagged six brace of as fine woodcock as you would wish to see..." (Alexandria Gazette, 10 August 1858).

Marsh Wrens were formerly abundant in the marshes bordering the Potomac River where "Hundreds of the large globular nests, affixed to the swaying reeds, used to be found in the bit of marsh bordering the Lee estate, and thence toward the Virginia end of long Bridge" (Coues and Prentiss 1883:44). With the destruction of those marshes, DMP is now the sole upriver tidal freshwater marsh where these wrens breed. In 1950 Irston Barnes counted 87 singing males at DMP (Davis, 1950), but by 1994 only 31 territories were found (S. Spencer, pers. obs.).

Early Christmas bird counts and other reports included some rare birds: Yellow-throated Warbler (1915), Red and White-winged crossbills (1916, 1917), Ruffed Grouse (adult and young, 1894), nesting Red-shouldered Hawks (1920), and breeding Prothonotary Warbler (1922). Halle (1947) provided fascinating descriptions of DMP and its wildlife--flocks of ducks, Bald Eagles, nesting Ospreys, and Marsh Wrens in profusion. His book was illustrated by the famous artist, Francis Lee Jaques, whose drawings of wildlife of the region and elsewhere are legendary. Uhler, in his presen-

TABLE 4. Bird species found on breeding bird surveys (1992-2000) in and near Dyke Marsh Preserve

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|
| Number of species found | 57 | 72 | 75 | 80 | 85 | 81 | 81 | 75 | 76 |
| Number of confirmed breeders | 26 | 31 | 34 | 37 | 37 | 42 | 32 | 34 | 36 |

TABLE 5. Numbers of species found in general groups at Dyke Marsh Preserve.

| | |
|---|---|
| waterfowl and divers | 30 |
| waders | 13 |
| hawks and owls | 13 |
| quail and doves | 3 |
| marsh birds | 5 |
| shorebirds | 29 |
| gulls and terns | 15 |
| woodpeckers | 7 |
| cuckoos, goatsuckers, swift, hummingbird, kingfisher | 7 |
| flycatchers and lark | 8 |
| swallows | 6 |
| crows and jay | 3 |
| wrens, thrushes, mimics | 15 |
| chickadees, titmouse, nuthatches | 5 |
| starling, kinglets | 5 |
| vireos | 6 |
| wood warblers | 34 |
| tanagers and sparrows | 17 |
| blackbirds, orioles | 7 |
| finches | 6 |

tations to the U. S. Congress (1963, 1968), noted the abundance of waterfowl and their favorite foods supplied by the marsh.

Breeding bird surveys of the picnic area, marina, haul road, and DMP were taken from 1992 to 2000 (L. Cartwright, pers. comm.; Table 4). Confirmed breeders over these years included waterfowl (Canada Goose, Mallard, Wood Duck), Osprey, and 10 neotropical migrants (flycatchers, warblers, vireos, orioles). Population trends cannot be derived from these data because of annual variations in observer-hours.

In 1992, Erika Wilson created a DMP database that consisted of 6,272 records of 202 species recorded from 1954-1991, with the bulk of the records occurring from 1985-1991. A check-list ("Birds of Dyke Marsh") issued by the National Park Service included Wilson's records and consisted of 208 species, but through 2000 the total is approximately 246 (Kurt Gaskill, pers. comm.) (Appendix F). Those species fall into general groups (Table 5). Clearly, DMP provides an important series of habitats for

TABLE 6. Generalized feeding categories of bird species at Dyke Marsh Preserve.

| | |
|---|---|
| Piscivorous (fish-eating) | 13% |
| Carnivorous (eating other vertebrates) | 5% |
| Insectivorous (insects and other arthropods) | 63% |
| Granivorous (seeds, fruits) | 13% |
| Other (omnivores, scavengers, pollen) | 6% |

TABLE 7 -Generalized feeding categories of mammal species at Dyke Marsh Preserve

| | |
|---|---|
| Insectivores | 10 |
| Insect and seed-eating | 8 |
| Herbivores | 3 |
| Carnivores | 5 |
| Omnivores | 4 |

feeding, resting, and breeding to groups such as waterfowl and neotropical migrants, such as wood warblers.

The same species can be placed into generalized feeding categories (Table 6). Insectivores are the most commonly found species.

The bird records *en toto* from DMP show that some species have been lost as breeding birds over the years (Wilson, 1991), many shorebirds, waterfowl and neotropical migrants use the site for refueling in migration, both waterfowl and neotropical migrants breed there, and that birds play important roles in the DMP ecosystem.

### Mammals

Historical records of mammals in and near DMP are few. Oberholser (1895) found four common mammal species at Belle Haven in June 1895. Bailey's (1896) "List of mammals of the District of Columbia," included some observations from Alexandria and Mount Vernon but none specifically from the DMP area. Kelso et al. (1993) believed that large-scale dredging in DMP caused the apparent decline of muskrats. Both Abbott (1976) and Parsons et al. (1976) provided lists of mammals seen at DMP and some nearby areas (Appendix G). Walter Bulmer has begun to survey current mammalian life at DMP. Using live traps and observations from 1996 through 1999, he has found mammal species similar to those reported in the two earlier studies (Appendix G).

Indicating roles played in the marsh ecosystem, the mammal species reported in these three surveys fall into categories (Table 7). As with birds, most mammals found in DMP are insectivores.

## ECOSYSTEM CHARACTERISTICS

As indicated above, the mudflats associated with DMP perform important general ecological functions including foraging and nursery areas for avian species, fisheries habitat, nutrient assimilation, water quality maintenance, and floodflow attenuation.

Mud flats contain nutrient rich sediments which support phytoplankton and zooplankton communities. The presence of these communities is particularly important to the production of benthic invertebrates and subsequent richness of fisheries and avian resources occurring in the region.

Aquatic species distribution and abundance are controlled by physical, chemical, and biological water parameters such as salinity, dissolved oxygen, temperature, pH, depth, nutrient levels, and substrate composition. Estuarine systems as represented by DMP characteristically possess higher concentrations of nutrients than the Chesapeake Bay or contributing freshwater systems. The underlying source for relatively higher nutrient concentrations arises from a biodepositional process initiated by the large "sediment bank" which these systems maintain. Sediments act to retain and release nitrates and phosphates which are essential to the production of microflora and suspension-feeding fauna. The interrelationship between the presence of zooplankton/phytoplankton and other "higher" life forms such as benthic invertebrates, fish, birds and mammals is generally recognized as an association of interdependency.

Such interdependencies at DMP can be represented by food chains which are of two basic types: grazing food chain and the detritus food chain. Food webs integrate several food chains to demonstrate alternate pathways.

Some concise food chains at DMP:

**Grazing food chain (semi-aquatic)**
**green plants → seeds → waterfowl, mice**

**Grazing food chain (terrestrial)**
**green plants → shoots, leaves, underground parts → insects, mice → shrews, birds**

**Detritus food chain (particulate and dissolved)**
**detritus on mudflats → zooplankton, crustaceans, microbes → fish, shorebirds**

**Aquatic food chain**
**dead plants and animal parts → fungi and bacteria, detritus → detritus consumers (invertebrates, minnows) → simple organic/inorganic compounds → small carnivores (small game fish, predacious arthropods) → large (top) carnivores (large game fish, fish-eating birds)**

Interrelationships or interdependencies are the keys to functioning and sustained ecosystems. When any of the links in food chains are disrupted or destroyed, some particular faunal or floral element will be disturbed and perhaps eliminated from the ecosystem. This is especially true of the top carnivores, because previous ecological studies have unequivocally demonstrated that elimination of large carnivores such as mountain lions or bears often precipitates the loss or drastic transformation of the ecosystem. Thus, for DMP it can be concluded that persistence of the marsh depends on maintenance of its manifold interrelationships among its many biological elements and the essential non-living components of the environment.

## MANAGEMENT RECOMMENDATIONS

Any management plan for the DMP area should consider the separate parts of the area, especially because some parts, as identified below, can play an integral role on the stability and even existence of the marsh itself. The area is here divided into (1) the mouth of Hunting Creek and Hunting Creek Bay, (2) Belle Haven picnic area, (3) Belle Haven marina, (4) the George Washington Trail, (5) DMP proper, and (6) the adjacent Potomac River. Recreational uses of all these areas are high at certain times of the year.

(1) The mouth of Hunting Creek contains run-off waters of the creek itself which in turn drains upland areas and those of some marshlands abutting I-95. Partly because of tidal fluctuations, the mouth of the creek and the Bay periodically expose extensive mudflats. As pointed out above, these mudflats contain nutrient rich sediments which support bacteria, fungi, phytoplankton and zooplankton communities, thus providing foraging sites for migrating shorebirds and wading birds, as well as fisheries habitat and nurseries. It is also extremely important for a wintering population of Bald Eagles. Construction of a new Wilson Bridge will undoubtedly severely impact this habitat.

(2) The picnic area is a partially wooded area which fronts the Potomac River and contains picnic tables, parking lots, and restroom facilities.

(3) The marina, comprised chiefly of fill material, was established in the 1950s and is managed by a private concessioner under contract to the National Park Service. It contains rental slips and moorings for approximately 140 boats many of which are sail boats.

(4) The Mount Vernon Trail is an extensive multi-purpose trail stretching some 18 miles from the Mount Vernon Estate to Roosevelt Island. Its principal uses at all seasons, but especially in the warmer months, include visits by walkers, joggers, cyclists, and roller-bladers. The trail is principally along the eastern edge of DMP's forested zones but also includes a boardwalk through the open marsh. (5) DMP proper, the principal object of this detailed report, consists of three zones--the open marsh, a swamp forest, and a floodplain forest. The northern end of the preserve has a main access trail which ends in the Haul Road, a filled strip extending partway into the marsh. Because DMP is the last remaining upstream tidal freshwater marsh on the Potomac River, it probably provides the [only] habitat for several animal species: the Marsh Wren, Least Bittern, Rice Rat, and perhaps Willow Flycatcher and Swamp Sparrow. It also probably contains the remaining upstream populations of wild rice and some rare plants.

(6) The adjacent Potomac River has the potentiality of a negative effect on DMP. Construction of another Wilson Bridge might produce intolerable sediment loads, and any increase in pollution would also drastically affect stability of the preserve.

Several management plans have been suggested, and to some extent implemented, for DMP. Continued focus, diligence and monitoring should be given to:

1. protecting water quality in DMP, especially by working with municipalities and the boat marina. Poor water quality may pose the most significant threat to wildlife by causing negative impacts on food sources and community stability. Monitoring all pollution components, such as sewage effluents, oils, and debris, as well as sedimentation and wave actions, is essential. An important key to the future of DMP is implementation of improved soil erosion and pollution controls;

2. monitoring the invasion and spread of exotic plants and animals which assuredly will affect natural communities;

3. maintaining forested buffers abutting the marsh;

4. working with the National Park Service and other organizations to maintain and improve natural heritage values of this area.

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## APPENDIX A

PERTINENT LEGISLATION

SEE DETAILED ACCOUNT: "Dyke Marsh: Legislative history and intent." 19 May 1981. Friends of Dyke Marsh, Alexandria, Va

### Act of May 23, 1928 (P.L. 493)

The Act of May 23, 1928 authorized and directed the United States Commission for the Celebration of the Two Hundredth Anniversary of the Birth of George Washington to take such steps as necessary to construct a suitable memorial highway to connect Mount Vernon with the south end of Memorial Bridge, then under construction. It also authorized the Secretary of Agriculture to cooperate with the Commission in carrying out the provisions of this act. The Secretary was authorized to acquire land, and when constructed to maintain and control pedestrian and vehicular traffic so that it did not interfere with the current jurisdiction of the State of Virginia.... As a result of this act the northern area of Dyke Marsh/Belle Haven was acquired through condemnation on November 23, 1933.

### Capper-Cramton Act of May 29, 1930 (P.L. 71-284)

This act provided for the acquisition, establishment, and development of the George Washington Memorial Parkway along the Potomac River from Mount Vernon and Fort Washington to Great Falls, and provided for acquisition of lands in the States of Maryland and Virginia requisite to the comprehensive park, parkway and playground system of the Nations Capital.

### Act of June 11, 1959 (P.L. 86-41)

This act provided for the acquisition of certain lands belonging to the Smoot Sand and Gravel Corporation (SSGC), in exchange for certain dredging and other rights on land already owned by the United States on the east side of the Mount Vernon Memorial Highway in Fairfax County, Virginia, in order to protect the Mount Vernon Memorial Highway, to add further to its memorial character, and in order to acquire an area of irreplaceable wetlands near the Nation's Capital which is valuable for the production and preservation of wildlife.

### Agreement between Charles and Elizabeth Fairchild and The Secretary of Interior, June 30, 1970

This agreement between the Fairchild and the Secretary of Interior was signed on June 30, 1970 and deeded approximately 28 acres to the United States for a cost of $10.00. This agreement was signed after permission was granted in an agreement signed by the Secretary of Interior on June 5, 1970, to construct an access on 1.3 acres of government property adjacent to the forty-two acre tract owned by RF & P Railroad company, and leased by Fairchild Co., Inc.

## APPENDIX B

Beetle (1973) provided a checklist of the land and freshwater mollusks of Virginia and therein identified 35 species known from Fairfax County at that time. These species should be looked for in DMP and the surrounding areas.

| | |
|---|---|
| *Alasmidonta undulata* | *Alasmidonta varicosa* |
| *Lasmigona subviridis* | *Elliptio lanceolata* |
| *Lampsilis cariosa* | *Lampsilis radiata* |
| *Viviparus georgianus* | *Lioplax subcarinata* |
| *Valvata tricarinata perconfusa* | *Lyogyrus granum* |
| *Amnicola limosa* | *Cochliopa virginica* |
| *Gillia altilis* | *Pomatiopsis lapidaria* |
| *Bithynia tentaculata* | *Goniobasis virginica* |
| *Physa ancillaria* | *Physa acuta* |
| *Physa heterostropha* | *Stagnicola caperata* |
| *Pseudosuccinea columella* | *Helisoma trivolvis* |
| *Planorbula armigera* | *Gyraulus deflectus* |
| *Menetus dilatatus* | *Ferrissia parallela* |
| *Ferrissia rivularis* | *Carychium exiguum* |
| *Gastrocopta cristata* | *Vertigo milium* |
| *Strobilops aenea* | *Strobilops labyrinthica* |
| *Philomycus carolinianus flexuolaris* | *Discus patulus* |
| *Anguispira alternata angulata* | *Anguispira a. fergusoni* |
| *Anguispira a. mordax* | *Punctum vitreum* |
| *Glyphyalinia rhoadsi* | *Stenotrema barbatum* |
| *Stenotrema fraternum* | *Triodopsis fallax* |
| *Triodopsis juxtidens* | *Triodopsis denotata* |

## APPENDIX C

Table C-1. The number of hexapod taxa found in 1998 and expected in the DMP. Data from E. Barrows.

| Subclass, order | Number of species found[1] | expected[2] |
|---|---|---|
| Subclass Entognatha (Entognathan Hexapods) | | |
| Collembola (Springtails) | 0 | 81 |
| Diplura (Diplurans) | 0 | 1 |
| Protura (Proturans) | 0 | 1 |
| Subclass Insecta (Insects) | | |
| Blattaria (Cockroaches | 0 | 1 |
| Coleoptera (Beetles) | 59 | 1,606 |
| Dermaptera (Earwigs) | 1 | 1 |
| Diptera (Flies) | 60 | 1,243 |
| Ephemeroptera (Mayflies) | 1 | 58 |
| Embiidina (Webspinners) | 0 | 0 |
| Grylloblattaria (Rock Crawlers) | 0 | 0 |
| Hemiptera (Stink Bugs and kin) | 8 | 272 |
| Homoptera (Aphids and kin) | 10 | 364 |
| Hymenoptera (Ants, Bees, Wasps) | 102 | 1,190 |
| Isoptera (Termites) | 1 | 1 |
| Lepidoptera (Butterflies, Moths) | 29 | 684 |
| Mantodea (Mantids) | 0 | 4 |
| Mecoptera (Scorpionflies) | 1 | 5 |
| Microcoryphia (Bristletails) | 0 | 1 |
| Neuroptera (Lacewinqs and kin) | 3 | 33 |
| Odonata (Damselflies, Dragonflies) | 6 | 71 |
| Orthoptera (Grasshoppers and kin) | 3 | 110 |
| Phasmida (Walkingsticks) | 0 | 1 |
| Plecoptera (Stoneflies) | 5 | 45 |
| Psocoptera (Bark Lice) | 0 | 18 |
| Pthiraptera (Lice) | 0 | 37 |
| Siphonaptera (Fleas) | 0 | 7 |
| Strepsiptera (Twisted-wing Parasites) | 0 | 5 |
| Thysanoptera (Thrips) | 0 | 33 |
| Thysanura (Silverfish) | 0 | 2 |
| Trichoptera (Caddisflies) | 3 | 17 |
| Zoraptera (Zorapterans) | 0 | 0 |
| Total (ca. 5%) | 292 | 6,000 |

[1] These numbers are from a preliminary examination of 8 of the 21 sets of specimens and field examinations of living hexapods in the Preserve.

[2] These numbers are based on an extrapolation of a count of 12,520 hexapod species in North Carolina (Wray 1967). It is hypothesized that there are 6,000 hexapod species in the Preserve because of its general geographic location, habitats, and my experience with the number of hexapods in the Washington, DC, area. Some of these orders (e.g., Collembola, Diplura) are infrequently captured in Malaise traps.

Table C-2. Hexapod orders found in the DMP and their foods. All hexapods consume bacteria and protistans when these organisms are on their usual foods. Species often have unique diets and some change their diets as they develop. Data are from Borror and White (1970), Borror et al. (1989), Cummins and Merritt (1984), and Edward Barrows (pers. obs.).

Subclass Entognatha
- (Entognathan Hexapods)
- Collembola (Springtails): algae, arthropod feces, bacteria, dead organic matter, fungi, pollen
- Diplura (Diplurans): probably dead organic matter
- Protura (Proturans): dead organic matter, fungus spores

Subclass Insecta (Insects)
- Blattaria (Cockroaches): dead organic matter, fruit
- Coleoptera (Beetles): all kinds of organic matter
- Dermaptera (Earwigs): dead and living plant parts, other living insects
- Diptera (Flies): all kinds of organic matter
- Ephemeroptera (Mayflies): chiefly algae and detritus in bodies of water
- Hemiptera (Stink Bugs and kin): dead and living plant parts, living insects
- Homoptera (Aphids and kin): living plants
- Hymenoptera (Ants, Bees, Wasps):organic matter.
- Isoptera (Termites): dead and living plant parts
- Lepidoptera (Butterflies, Moths): usually living plant parts, sometimes dead animal and plant parts, beeswax, living insects, pollen
- Mantodea (Mantids): living insects, sometimes small birds
- Mecoptera (Scorpionflies): chiefly dead and living insects, mosses
- Microcoryphia (Bristletails): chiefly algae, but also decaying fruits, lichens, and mosses
- Neuroptera (Lacewings and kin): freshwater sponges, living insects, spider eggs
- Odonata (Damselflies, Dragonflies): other living insects, sometimes aquatic vertebrates
- Orthoptera (Grasshoppers and kin): dead and living plant parts, other living insects
- Phasmida (Walkingsticks): living plant parts
- Plecoptera (Stoneflies): carrion, detritus, fungi, other living insects, dead and living plant parts, seeds, whole small plants.
- Psocoptera (Barklice): algae, cereals, dead insects and plants, lichens, molds, pollen.
- Pthiraptera (Lice): vertebrate tissues
- Siphonaptera (Fleas): vertebrate tissues
- Strepsiptera (Twisted-wing Parasites): bees
- Thysanoptera (Thrips): fungus spores, living insects, chiefly living plants
- Thysanura (Silverfish): dead organic matter.
- Trichoptera (Caddisflies): detritus, fungi, other living insects, dead and living plant parts, seeds, whole small plants.

## APPENDIX D

Fish species reported from DMP and the adjacent Potomac River with documentation from Jenkins and Burkhead (*) and from Wayne Starnes (**, pers. comm.). Data on residency and feeding habits were supplied by Wayne Starnes. The fish species reported by Parsons et al. (1976) from the Belle Haven estuary are all included except for the banded killifish.

| SPECIES | RESIDENCY | FEEDING HABIT |
|---|---|---|
| Lampreys: | | |
| *Petromyzon marinus* (Sea lamprey) | anadromous | external parasite |
| Sturgeons: | | |
| **Acipenser brevirostrum* (Shortnose sturgeon) | apparently extirpated | |
| **Acipenser oxyrhynchus* | very rare | |
| Gars: | | |
| **Lepisosteus osseus* (Longnose gar) | migratory | predator |
| Bowfins: | | |
| **Amia calva* | | predator |
| Freshwater eels: | | |
| **Anguilla rostrata*[1] (American eel) | catadromous (omnivore) | predator |
| Herrings: | | |
| **Dorosoma cepedianum* (Gizzard shad) | permanent, breeding | filter-feeding |
| **Dorosoma petenense* (Threadfin shad) | | filter-feeding |
| **Alosa aestivalis*[1] (Blueback herring) | migratory, breeding | filter-feeding |
| **Alosa pseudoharengus*[1] (Alewife) | migratory, larvae | filter-feeding |
| **Alosa mediocris* (Hickory shad) | migratory, breeding very rare | predator |
| **Alosa sapidissima* (American shad) | migratory, breeding becoming rare | predator |
| Pikes: | | |
| **Esox niger* (Chain pickerel) | predator | |

*continued*

*APPENDIX D continued*

| SPECIES | RESIDENCY | FEEDING HABIT |
|---|---|---|
| Minnows: | | |
| **Cyprinus carpio*[1] (Common carp) | permanent, breeding | omnivore |
| **Carassius auratus* (Goldfish) | | omnivore |
| **Notemigonus crysoleucas* (Golden shiner) | | predator on small inverts. |
| **Clinostomus funduloides* (Rosyside dace) | | predator on small inverts. |
| **Rhinichthys cataractae* (Longnose dace) | | predator on small inverts. |
| **Rhinichthys atratulus* (Blacknose dace) | | predator on small inverts. |
| **Semotilus atromaculatus* (Creek chub) | | omnivore |
| **Cyprinella analostana* (Satinfin shiner) | | predator on small inverts. |
| **Cyprinella spiloptera* (Spotfin shiner) | | predator on small inverts. |
| **Luxilus cornutus* (Common shiner) | | predator on small inverts. |
| **Notropis rubellus* (Rosyface shiner) | | predator on small inverts. |
| **Notropis amoenus* (Comely shiner) | | predator on small inverts. |
| **Notropis hudsonius*[1] (Spottail shiner) | permanent, breeding | predator on small inverts. |
| *Notropis procne (Swallowtail shiner) | | predator on small inverts. |
| **Notropis bifrenatus* (Bridle shiner) | | predator on small inverts. |
| **Pimephales notatus* (Bluntnose minnow) | | predator on small inverts. |
| Suckers: | | |
| **Carpiodes cyprinus* (Quillback) | | predator on small inverts. detritus |
| **Erimyzon oblongus* (Creek chubsucker) | | plankton |

*continued*

*APPENDIX D continued*

| SPECIES | RESIDENCY | FEEDING HABIT |
|---|---|---|
| **Hypentelium nigricans* (Northern hogsucker) | | predator on small inverts. |
| **Moxostoma macrolepidotum* (Shorthead redhorse) | | predator on small inverts. detritus |
| **Catostomus commersoni* (White sucker) | | predator on small inverts. detritus |
| Bullhead catfishes: | | |
| **Ictalurus furcatus* (Blue catfish) | rare | predator on inverts.,fish |
| **Ictalurus punctatus*[1] (Channel catfish) | permanent, breeding | predator on inverts.,fish |
| **Ameiurus catus*[1] (White catfish) | permanent, breeding | omnivore |
| **Ameiurus natalis* (Yellow bullhead) | | omnivore |
| **Ameiurus nebulosus*[1] (Brown bullhead) | permanent, breeding | omnivore |
| **Noturus gyrinus* (Tadpole madtom) | | omnivore |
| Killifishes: | | |
| **Fundulus diaphanus*[1] (Banded killifish) | permanent, breeding | predator on small inverts. |
| Livebearers: | | |
| **Gambusia holbrookii*[1] (Eastern mosquitofish) | permanent, breeding | predator on small inverts. |
| Striped basses: | | |
| **Morone americana*[1] (White perch) | migratory, breeding | predator on small inverts, fish |
| **Morone saxatilis*[1] (Striped bass) | migratory, breeding | predator on inverts.,fish |
| Sunfishes: | | |
| **Pomoxis nigromaculatus* (Black crappie) | | predator on inverts., fish |
| **Pomoxis annularis* (White crappie) | | predator on inverts., fish |
| **Enneacanthus gloriosus* (Bluespotted sunfish) | | predator on small inverts. |

*continued*

*APPENDIX D continued*

| SPECIES | RESIDENCY | FEEDING HABIT |
| --- | --- | --- |
| **Micropterus dolomieu* (Smallmouth bass) | | predator on inverts., fish |
| **Micropterus salmoides* (Largemouth bass) | permanent, breeding | predator on inverts., fish |
| **Lepomis gulosus* (Warmouth) | permanent, breeding | predator on inverts., fish |
| **Lepomis cyanellus* (Green sunfish) | permanent, breeding | predator on small inverts. |
| **Lepomis auritus* (Redbreast sunfish) | permanent, breeding | predator on small inverts. |
| **Lepomis macrochirus* (Bluegill) | permanent, breeding | predator on insects |
| **Lepomis gibbosus*[1] (Pumpkinseed) | permanent, breeding | predator on small inverts. |
| Perches: | | |
| **Perca flavescens*[1] (Yellow perch) | migratory and permanent, breeding | predator on inverts., fish |
| **Percina caprodes* (Logperch) | rare | predator on inverts. |
| **Percina maculata* (Blackside darter) | rare | predator on insects |
| **Etheostoma olmstedi* (Tesselated darter) | permanent, breeding | predator on small inverts. |
| Other: | | |
| ** *Brevoortia tyrannus*[1] (Atlantic menhaden) | migratory, breeding | filter-feeding (omnivore) |
| ** *Menidia beryllina* (Tidewater silverside) | permanent, breeding | predator on small inverts. |
| ** *Fundulus heteroclitus* (Mummichog) | permanent, breeding | predator on small inverts. |
| *Hyboganthus regius*[1] (E. Silvery minnow) | permanent, breeding | detritus |

[1] Listed as sport/commercial fish found near DMP (National Park Service 1976)

## APPENDIX E

Amphibians and reptiles reported from DMP by Walter Bulmer (1996-1999) and from nearby sites as indicated.

AMPHIBIANS

Salamanders

*Eurycea bislineata* (Two-lined salamander) common, woodland
*Plethodon cinereus* (Red-backed salamander)[2, 3] common, woodland[1]
*Notophthalmus viridescens* (E. newt)[2, 3] uncommon, forest ponds

Frogs and toads

*Bufo americanus* (American toad)[2, 3] common, woodland, marsh
*Bufo woodhousei* (Fowler's toad)[3] uncommon, woodland
*Acris crepitans* (N. Cricket frog)[2, 3] uncommon, woodland, marsh
*Hyla cinerea* (Green treefrog)[3] uncommon, marsh
*Hyla versicolor* (E. Gray treefrog)[3] common, woodland
*Pseudacris crucifer* (Spring peeper)[2, 3] uncommon, woodland
*Rana clamitans* (Green frog)[2, 3] common, marsh, woodland
*Rana catesbeiana* (Bullfrog)[2, 3] common, marsh
*Rana palustris* (Pickerel frog)[3] common, marsh, woodland
*Rana sphenocephala* (S. Leopard frog)[2, 3] uncommon, marsh

REPTILES

Turtles

*Chelydra serpentina* (Snapping turtle)[2, 3] common, marsh
*Chrysemys picta* (Painted turtle)[2, 3] common, marsh
*Pseudemys concinna* (River cooter) uncommon, marsh
*Pseudemys rubiventris* (Red-bellied turtle) common, marsh
*Terrapene carolina* (Box turtle) common, woodland
*Trachemys scripta* (Red-eared turtle)[2] common, marsh
*Kinosternon subrubrum* (Mud turtle)[2, 3] common, marsh
*Stenotherus odoratus* (Musk turtle)[2, 3] common, marsh

Lizards

*Scincella lateralis* (Ground skink)[2, 3] common, woodland
*Eumeces fasciatus* (Five-lined skink)[2, 3] common, woodland

Snakes

*Carphophis amoenus* (Worm snake)[3] uncommon, woodland
*Coluber constrictor* (Black racer)[2, 3] common, marsh, woodland
*Diadophis punctatus* (Ring-neck snake)[3] common, woodland
*Elaphe obsoleta* (Black rat snake)[2] common, woodland
*Nerioda sipedon* (N. water snake)[2, 3] common, marsh, woodland
*Opheodrys aestivus* (Rough green snake) uncommon, marsh, woodland
*Regina septemvittata* (Queen snake)[3] uncommon, marsh, woodland
*Storeria dekayi* (N .brown snake)[3] uncommon, marsh, woodland
*Thamnophis sauritus* (E. ribbon snake)[3] uncommon, marsh, woodland
*Thamnophis sirtalis* (E. garter snake)[2, 3] common, marsh, woodland

*Footnotes continued on next page.*

[1] woodland refers to a combination of swamp and floodplain forests.
[2] species reported in an unpublished list by David Abbott et al. (ca. 1976). These authors also reported Spotted salamander, Dusky salamander, Wood frog, Spotted turtle, Broad-headed skink, and Corn snake.
[3] species reported in nearby watersheds (Belle Haven, Little Hunting Creek, Dogue Creek) by Parsons et al. (1976). They also reported other species perhaps not all from DMP: Jefferson salamander, Spotted salamander, Marbled salamander, Dusky salamander, Two-lined salamander, Three-lined salamander, Four-toed salamander, Slimy salamander, Mud salamander, Red salamander, Chorus frog, Wood frog, Spotted turtle, Wood turtle, Diamondback terrapin, Florida cooter, Fence lizard, Broad-headed skink, Corn snake, Hognose snake, Mole snake, King snake, Milk snake, Red-bellied snake, Smooth earth snake.

## APPENDIX F

Birds of the DMP, adapted from a field check-list, "Birds of Dyke Marsh," National Park Service (1993), and updated to 2000 by Kurt Gaskill. Also includes Hunting Creek and Bay. Principal season of occurrence: P=resident, W=winter, S=summer, M=spring and/or fall migration. Breeding status (B=breeds or has bred) taken chiefly from the recent Breeding Bird Surveys. List does not include historical records: American Woodcock, Ruffed Grouse, Red Crossbill, White-winged Crossbill. Species marked with an asterisk (*) have not been seen since 1985.

---

Red-throated Loon (*Gavia stellata*). W
Common Loon (*Gavia immer*). M, W
Pied-billed Grebe (*Podilymbus podiceps*). B, M
Horned Grebe (*Podiceps auritus*). M
Double-crested Cormorant (*Phalacrocorax auritus*). S, M
Great Cormorant (*Phalacrocorax carbo*). M
American Bittern (*Botaurus lentiginosus*). M
Least Bittern (*Ixobrychus exilis*). S, B, M
Great Blue Heron (*Ardea herodias*). P
Great Egret (*Casmerodius albus*). P
Snowy Egret (*Egretta thula*). S, M
Little Blue Heron (*Egretta caerulea*). S, M
Tricolored Heron (*Egretta tricolor*). M
Cattle Egret (*Bubulcus ibis*). M
Green Heron (*Butorides virescens*). S, M
Black-crowned Night-heron (*Nycticorax nycticorax*). S, B, M
Yellow-crowned Night-heron (*Nyctanassa violaceus*). S, M *
White Ibis (*Eudocimus albus*). M *
Black Vulture (*Coragyps atratus*). S, M
Turkey Vulture (*Cathartes aura*). P
Snow Goose (*Chen caerulescens*). M, W
Canada Goose (*Branta canadensis*). B, P
Mute Swan (*Cygnus olor*). S, M
Tundra Swan (*Cygnus columbianus).* M, W
Wood Duck (*Aix sponsa*). B, P
Green-winged Teal (*Anas crecca*). M
American Black Duck (*Anas rubripes*). B, M, W

Mallard (*Anas platyrhynchos*). B, P
Northern Pintail (*Anas acuta*). M
Blue-winged Teal (*Anas discors*). M
Northern Shoveler (*Anas clypeata*). M
Gadwall (*Anas strepera*). M, W
Eurasian Wigeon (*Anas penelope*). W
American Wigeon (*Anas americana*). M
Canvasback (*Aythya valisineria*). M, W
Redhead (*Aythya americana*). M
Ring-necked Duck (*Aythya collaris*). M
Greater Scaup (*Aythya marila*). M
Lesser Scaup (*Aythya affinis*). M, W
Oldsquaw (*Clangula hyemalis*). M
Common Goldeneye (*Bucephala clangula*). M
Bufflehead (*Bucephala albeola*). M, W
Hooded Merganser (*Lophodytes cucullatus*). M, W
Common Merganser (*Mergus merganser*). M, W
Red-breasted Merganser (*Mergus serrator*). M
Ruddy Duck (*Oxyura jamaicensis*). M, W
Osprey (*Pandion haliaetus*). S, B, M
Bald Eagle (*Haliaeetus leucocephalus*). P
Northern Harrier (*Circus cyaneus*). M
Sharp-shinned Hawk (*Accipiter striatus*). M, W
Cooper's Hawk (*Accipiter cooperii*). M, W
Red-shouldered Hawk (*Buteo lineatus*). P
Broad-winged Hawk (*Buteo platypterus*). M
Red-tailed Hawk (*Buteo jamaicensis*). P
American Kestrel (*Falco sparverius*). P
Merlin (*Falco columbarius*). M
Peregrine Falcon (*Falco peregrinus*). M
Northern Bobwhite (*Colinus virginianus*). S, P?
King Rail (*Rallus elegans*). S, M
Virginia Rail (*Rallus limicola*). S, M
Sora (*Porzana carolina*). M
Common Moorhen (*Gallinula chloropus*). B, M
American Coot (*Fulica americana*). M, W
Sandhill Crane (*Grus canadensis*). M
Black-bellied Plover (*Pluvialis squatarola*). M
American Golden-plover (*Pluvialis dominica*). M
Semipalmated Plover (*Charadrius semipalmatus*). M
Killdeer (*Charadrius vociferus*). P
American Avocet (*Recurvirostra americana*). M
Greater Yellowlegs (*Tringa melanoleuca*). M
Lesser Yellowlegs (*Tringa flavipes*). M
Solitary Sandpiper (*Tringa solitaria*). M
Willet (*Cataptrophorus semipalmatus*). M

Spotted Sandpiper (*Actitis macularia*). M
Hudsonian Godwit (*Limosa haemastica*). M
Marbled Godwit (*Limosa fedoa*). M
Ruddy Turnstone (*Arenaria interpres*). M
Red Knot (*Calidris canutus*). M
Sanderling (*Calidris alba*). M
Semipalmated Sandpiper (*Calidris pusilla*). M
Western Sandpiper (*Calidris mauri*). M
Least Sandpiper (*Calidris minutilla*). M
White-rumped Sandpiper (*Calidris fuscicollis*). M
Baird's Sandpiper (*Calidris bairdii*). M
Pectoral Sandpiper (*Calidris melanotos*). M
Dunlin (*Calidris alpina*). M
Stilt Sandpiper (*Calidris himantopus*). M
Ruff (*Philomachus pugnax*). M
Short-billed Dowitcher (*Limnodromus griseus*). M
Long-billed Dowitcher (*Limnodromus scolopaceus*). M
Common Snipe (*Gallinago gallinago*). M, W
Wilson's Phalarope (*Phalaropus tricolor*). M
Red-necked Phalarope (*Phalaropus lobatus*). M
Parasitic Jaeger (*Stercorarius parasiticus*). M
Laughing Gull (*Larus atricilla*). S, W
Franklin's Gull (*Larus pipixcan*). M
Little Gull (*Larus minutus*). M
Bonaparte's Gull (*Larus philadelphia*). M
Ring-billed Gull (*Larus delawarensis*). S, W
Herring Gull (*Larus argentatus*). S, W
Lesser Black-backed Gull (*Larus fuscus*). M
Great Black-backed Gull (*Larus marinus*). S, W
Caspian Tern (*Sterna caspia*). S, M
Royal Tern (*Sterna maxima*). S, M
Common Tern (*Sterna hirundo*). M
Forster's Tern (*Sterna forsteri*). S, M
Least Tern (*Sterna antillarum*). S
Black Tern (*Chlidonias niger*). M
Black Skimmer (*Rynchops niger*). M
Rock Dove (*Columba livia*). P
Mourning Dove (*Zenaida macroura*). B, P
Black-billed Cuckoo (*Coccyzus erythropthalmus*). S, M
Yellow-billed Cuckoo (*Coccyzus americanus*). S, B, M
Eastern Screech-Owl (*Otus asio*). P *
Great Horned Owl (*Bubo virginianus*). B, P
Barred Owl (*Strix varia*). P
Common Nighthawk (*Chordeiles minor*). M
Whip-poor-will (*Caprimulgus vociferus*). M *
Chimney Swift (*Chaetura pelagica*). S, M

Ruby-throated Hummingbird (*Archilochus colubris*). S, B, M
Belted Kingfisher (*Ceryle alcyon*). B?, P
Red-headed Woodpecker (*Melanerpes erythrocephalus*). M
Red-bellied Woodpecker (*Melanerpes carolinus*). B, P
Yellow-bellied Sapsucker (*Sphyrapicus varius*). W
Downy Woodpecker (*Picoides pubescens*). B, P
Hairy Woodpecker (*Picoides villosus*). B, P
Northern Flicker (*Colaptes auratus*). B, P
Pileated Woodpecker (*Dryocopus pileatus*). B, P
Eastern Wood-pewee (*Contopus virens*). S, M
Yellow-bellied Flycatcher (*Empidonax flavescens*). M
Acadian Flycatcher (*Empidonax virescens*). S, M
Willow Flycatcher (*Empidonax traillii*). S, M
Least Flycatcher (*Empidonax minimus*). M
Eastern Phoebe (*Sayornis phoebe*). S, M
Great Crested Flycatcher (*Myiarchus crinitus*). S, B, M
Eastern Kingbird (*Tyrannus tyrannus*). S, B, M
White-eyed Vireo (*Vireo griseus*). S, B, M
Blue-headed Vireo (*Vireo solitarius*). M
Yellow-throated Vireo (*Vireo flavifrons*). S, M
Warbling Vireo (*Vireo gilvus*). S, B, M
Philadelphia Vireo (*Vireo philadelphicus*). M
Red-eyed Vireo (*Vireo olivaceus*). S, B, M
Blue Jay (*Cyanocitta cristata*). B, P
American Crow (*Corvus brachyrhynchos*). B, P
Fish Crow (*Corvus ossifragus)*. P
Horned Lark (*Eremophila alpestris*). M *
Purple Martin (*Progne subis*). S, B, M
Tree Swallow (*Tachycineta bicolor*). S, B, M
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*). S, B. M.
Bank Swallow (*Riparia riparia*). M
Cliff Swallow (*Hirundo pyrrhonota*). M
Barn Swallow (*Hirundo rustica*). S, B, M
Black-capped Chickadee (*Poecile atricapillus*). W *
Carolina Chickadee (*Poecile carolinensis*). B, P
Tufted Titmouse (*Baeolophus bicolor*). B, P
Red-breasted Nuthatch (*Sitta canadensis*). M *
White-breasted Nuthatch (*Sitta carolinensis*). S, P
Brown Creeper (*Certhia americana*). W
Carolina Wren (*Thryothorus ludovicianus*). B, P
House Wren (*Troglodytes aedon*). S, M, W
Winter Wren (*Troglodytes troglodytes*). W
Marsh Wren (*Cistothorus palustris)*. B, M
Golden-crowned Kinglet (*Regulus satrapa*). M, W
Ruby-crowned Kinglet (*Regulus calendula*). M, W
Blue-gray Gnatcatcher (*Polioptila caerulea*). S, B, M

Eastern Bluebird (*Sialia sialis*). S, M
Veery (*Catharus fuscescens*). M
Gray-cheeked Thrush (*Catharus minimus*). M *
Swainson's Thrush (*Catharus ustulatus*). M
Hermit Thrush (*Catharus guttatus*). M, W
Wood Thrush (*Hylocichla mustelina*). S, M
American Robin (*Turdus migratorius*). S, B, M
Gray Catbird (*Dumetella carolinensis*). S, B, M
Northern Mockingbird (*Mimus polyglottos*). B, P
Brown Thrasher (*Toxostoma rufum*). S, P
European Starling (*Sturnus vulgaris*). B, P
American Pipit (*Anthus rubescens*). W
Cedar Waxwing (*Bombycilla cedrorum*). S, B, M
Blue-winged Warbler (*Vermivora pinus*). M
Golden-winged Warbler (*Vermivora chrysoptera*). M *
Tennessee Warbler (*Vermivora peregrina*). M
Orange-crowned Warbler (*Vermivora celata*). M, W *
Nashville Warbler (*Vermivora ruficapilla*). M
Northern Parula (*Parula americana*). S, B, M
Yellow Warbler (*Dendroica petechia*). S, B, M
Chestnut-sided Warbler (*Dendroica pensylvanica*). M
Magnolia Warbler (*Dendroica magnolia*). M
Cape May Warbler (*Dendroica tigrina*). M
Black-throated Blue Warbler (*Dendroica caerulescens*). M
Yellow-rumped Warbler (*Dendroica coronata*). M, W
Black-throated Green Warbler (*Dendroica virens*). M
Blackburnian Warbler (*Dendroica fusca*). M
Yellow-throated Warbler (*Dendroica dominica*). M
Pine Warbler (*Dendroica pinus*). M
Prairie Warbler (*Dendroica discolor*). M
Palm Warbler (*Dendroica palmarum*). M
Bay-breasted Warbler (*Dendroica castanea*). M
Blackpoll Warbler (*Dendroica striata*). M
Black-and-white Warbler (*Mniotilta varia*). S, M
American Redstart (*Setophaga ruticilla*). S, M
Prothonotary Warbler (*Protonotaria citrea*). S, B, M
Worm-eating Warbler (*Helmitheros vermivorus*). M
Ovenbird (*Seiurus aurocapillus*). M
Northern Waterthrush (*Seiurus noveboracensis*). M
Louisiana Waterthrush (*Seiurus motacilla*). S, M
Kentucky Warbler (*Oporornis formosus*). S, M
Mourning Warbler (*Oporornis philadelphia*). M *
Common Yellowthroat (*Geothlypis trichas*). S, M, P?
Hooded Warbler (*Wilsonia citrina*). M
Wilson's Warbler (*Wilsonia pusilla*). M
Canada Warbler (*Wilsonia canadensis*). M

Yellow-breasted Chat (*Icteria virens*). M
Summer Tanager (*Piranga rubra*). M
Scarlet Tanager (*Piranga olivacea*). S, B, M
Eastern Towhee (*Pipilo erythrophthalmus*). S, M
American Tree Sparrow (*Spizella arborea*). W
Chipping Sparrow (*Spizella passerina*). S, M
Field Sparrow (*Spizella pusilla*). S, M
Savannah Sparrow (*Passerculus sandwichensis*). M, W
Fox Sparrow (*Passerella iliaca*). M
Song Sparrow (*Melospiza melodia*). B, M
Lincoln's Sparrow (*Melospiza lincolnii*). M
Swamp Sparrow (*Melospiza georgiana*). S, B, M
White-throated Sparrow (*Zonotrichia albicollis*). M, W
White-crowned Sparrow (*Zonotrichia leucophrys*). M, W
Dark-eyed Junco (*Junco hyemalis*). W
Snow Bunting (*Plectrophenax nivalis*). W
Northern Cardinal (*Cardinalis cardinalis*). B, P
Rose-breasted Grosbeak (*Pheucticus ludovicianus*). M
Blue Grosbeak (*Guiraca caerulea*). M
Indigo Bunting (*Passerina cyanea*). S, M
Bobolink (*Dolichonyx oryzivorus*). M
Red-winged Blackbird (*Agelaius phoeniceus*). B, P
Eastern Meadowlark (*Sturnella magna*). M
Rusty Blackbird (*Euphagus carolinus*). M, W
Common Grackle (*Quiscalus quiscula*). S, B, M
Brown-headed Cowbird (*Molothrus ater*). S, B, M
Orchard Oriole (*Icterus spurius*). S, B, M
Baltimore Oriole (*Icterus galbula*). S, B, M
Purple Finch (*Carpodacus purpureus*). W
House Finch (*Carpodacus mexicanus*). B, W
Pine Siskin (*Carduelis pinus*). M, W *
American Goldfinch (*Carduelis tristis*). B, P
Evening Grosbeak (*Coccothraustes vespertinus*). M *
House Sparrow (*Passer domesticus*). B, P

## APPENDIX G

Mammals reported from DMP and nearby areas.

| | Abbott 1976[1] | Parsons et al. 1977 | Bulmer 1996-1999[3] |
|---|---|---|---|
| Virginia Opossum (*Didelphis virginiana*) | X | X | X |
| Northern Short-tailed Shrew (*Blarina brevicauda*) | X | X | X |
| Eastern Mole (*Scalopus aquaticus*) | | X | X |
| Star-nosed Mole (*Condylura cristata*) | | | X |
| Little Brown Myotis (*Myotis lucifugus*) | X | X | |
| Northern Red Bat (*Lasiurus borealis*) | X | X | |
| Hoary Bat (*Lasiurus cinereus*) | X | X | |
| Silver-haired Bat (*Lasionycteris noctivagans*) | | X | |
| Eastern Pipistrelle (*Pipistrellus subflavus*) | | X | |
| Big Brown Bat (*Eptesicus fuscus*) | X | X | |
| Evening Bat (*Nycticeius humeralis*) | | X | |
| Eastern Cottontail (*Sylvilagus floridanus*) | X | X | X |
| Eastern Chipmunk (*Tamias striatus*) | X | X | X |
| Woodchuck (*Marmota monax*) | | | X |
| Eastern Gray Squirrel (*Sciurus carolinensis*) | X | X | X |
| Southern Flying Squirrel (*Glaucomys volans*) | X | X | X |
| American Beaver (*Castor canadensis*) | X | X | X |
| Marsh Rice Rat (*Oryzomys palustris*) | X | | |
| Eastern Harvest Mouse (*Reithrodontomys humulis*) | X | | |
| White-footed Mouse (*Peromyscus leucopus*) | X | X | X |
| Deer Mouse (*Peromyscus maniculatus*) | X | | |
| Eastern Woodrat (*Neotoma floridana*)[2] | X | | |
| House Mouse (*Mus musculus*) | | | X |
| Norway Rat (*Rattus norvegicus*) | X | | |
| Black Rat (*Rattus rattus*) | X | X | |
| Meadow Vole (*Microtus pennsylvanicus*) | X | X | X |
| Common Muskrat (*Ondatra zibethicus*) | X | X | X |
| Red Fox (*Vulpes vulpes*) | X | X | X |
| Common Gray Fox (*Urocyon cinereoargenteus*) | X | X | X |
| Common Raccoon (*Procyon lotor*) | X | X | X |
| Mink (*Mustela vison*) | | X | |
| Striped Skunk (*Mephitis mephitis*) | X | X | X |
| Northern River Otter (*Lutra canadensis*) | X | X | |
| White-tailed Deer (*Odocoileus virginianus*) | X | | X |

[1]observations from 1968-1976
[2]unlikely
[3]not found currently but expected: Southeastern Shrew (*Sorex longirostris*), Least Shrew (*Cryptotis parva*), Little Brown Myotis, Silver-haired Bat, Eastern Pipistrelle, Red Bat, Hoary Bat, Marsh Rice Rat, Norway Rat, Meadow Jumping Mouse (*Zapus hudsonius*), Long-tailed Weasel (*Mustela frenata*), Mink, River Otter.