

# Vascular plants of a Delaware River tidal freshwater wetland and adjacent terrestrial areas: Seed bank and vegetation comparisons of reference and constructed marshes and annotated species list<sup>1</sup>

Mary Alessio Leck<sup>2,3</sup>

Biology Department, Rider University, Lawrenceville, NJ 08648

Charles F. Leck

Department of Ecology and Evolutionary Biology, Cook College, Rutgers University, New Brunswick, NJ 08901

LECK, M. A. (Dept. Biol., Rider Univ., Lawrenceville, NJ 08648) AND C. F. LECK (Dept. Ecol. & Evol. Biol., Cook College, Rutgers Univ., New Brunswick, NJ 08901). Vascular plants of a Delaware River tidal freshwater wetland and adjacent terrestrial areas: Seed bank and vegetation comparisons of reference and constructed marshes and annotated species list. *J. Torrey Bot. Soc.* 132: 323–354. 2005.—Constructed wetland soil samples contained many more species with densities > 100 seeds / m<sup>2</sup> than reference marsh ones (102 vs. 28); constructed wetland densities for many species were considerably higher and richness (species / sample) were > 2× greater than the reference marsh. Of the total 218 seed bank species, 60 were common to both and 34 occurred only in reference marsh samples. Numbers of cover species were similar, but composition differed. Invasive species, notably *Lythrum salicaria*, *Phalaris arundinacea*, and *Phragmites australis*, were more important in constructed wetland soil samples and vegetation. Non-native species comprised 9 % and 13 % of the reference marsh and constructed wetland seed bank species and 8 % and 12 % of the cover species, respectively. Variable dispersal patterns and *in situ* seed production contributed to these differences. Over the entire study area (wetlands and adjacent terrestrial areas) we recorded 875 species, representing 141 families, more than doubling the number observed in a 1988 report. The families having the most species were Asteraceae (103 species), Poaceae (100), and Cyperaceae (83). The largest genera were *Carex* (46) and *Polygonum* (19); seven other genera also had ≥ 10 species. Nine species were pseudo-viviparous, producing plantlets on inflorescences. Non-native species comprised 27 % of the total flora. Overall there were 37 NJ rare / endangered species for the entire area; 11 occurred only in the constructed wetland with constructed wetland soil samples containing more than the reference marsh samples (8 vs. 1). Available lists from 1824, 1887, and 1964/65 and five species known only from herbarium specimens indicate that several species have been extirpated since the 19<sup>th</sup> C. Anthropogenic influences continue to have impact on diversity.

Key words: biodiversity, constructed wetland, floristic survey, reference marsh, tidal freshwater marsh, wetland seed bank.

The Delaware River tidal freshwater marsh In New Jersey, USA, locally known as the Hamil-

ton—Trenton—Bordentown or Trenton Marsh, has been the focus of many vegetation studies beginning in the 1970s (e.g., Whigham and Simpson 1975, Simpson et al. 1983, Leck and

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<sup>3</sup> Author for correspondence, E-mail: leck@rider.edu  
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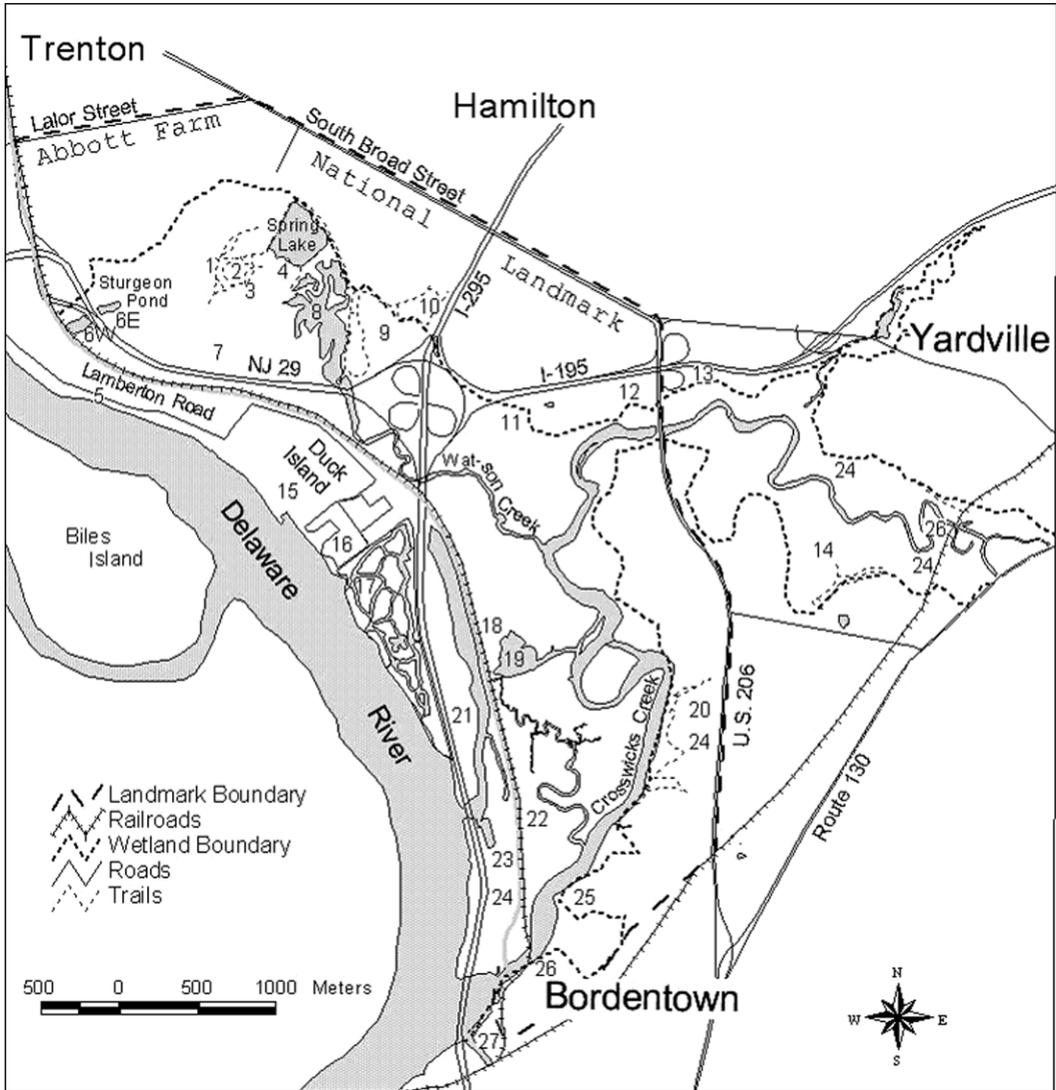


FIG. 1. Map of Hamilton—Trenton—Bordentown Marsh, including adjacent terrestrial habitats included in this survey. Numbered locations are: 1 Beaver Point, 2 Spring Lake trails, 3 Osprey Point, 4 Sunny Pond, 5 little mitigation site, 6 Sturgeon Pond (east and west), 7 landfill, 8 Rowan Lake, 9 Watson Woods, 10 site of Abbott's homestead, 11 reference / pre-existing marsh, 12 Hamilton sewage disposal plant, 13 Bordentown City water works, 14 Northern Community Park (Bordentown Township), 15 Public Service Gas & Electric Co., 16 gas and oil tanks, 17 Duck Island constructed wetland, 18 abandoned brick factory, 19 lagoon, 20 Bordentown Bluffs, 21 Duck Creek, 22 Conrail (Camden and Amboy) Railroad, 23 Delaware & Raritan Canal, 24 Delaware & Raritan Canal State Park, 25 Point Breeze, 26 railroad bridge, 27 Black Creek.

Simpson 1995, Leck 2003). In 1988 we summarized qualitative and quantitative data on distribution and abundance of plant species and provided descriptions of location, physiography, sediments, and geology as well as land use history (Leck et al. 1988). At that time we recorded 426 species.

The goals of this report are to provide a status summary of vegetation at two levels. First, we

make comparisons of both seed bank and vegetation of a reference marsh area and a constructed wetland and evaluate the impact of human-generated landscape disturbance. Such a comparison, particularly based on long-term studies, has not been made previously for this wetland and there are few studies comparing reference and constructed (or restored) wetlands that include seed bank data. Baldwin and De-

Rico (1999) is an exception. Second, we provide an annotated and updated view of plant species diversity that can provide insights regarding the quality of wetland and adjacent terrestrial plant communities, as well as a basis for encouraging management activities and developing educational uses (Delaware & Raritan Greenway, 1999). These could also provide a baseline for future floristic studies (Robinson et al. 1994).

**Survey Area.** OVERVIEW. The Marsh (Fig. 1) is located 3.5 km south of Trenton, New Jersey. It lies between industrialized land on Duck Island and urbanized land, associated with growth of Trenton, Hamilton Township, Bordentown City, Bordentown Township, and other communities. Wetlands are bounded by the Delaware River on the west and bordered by bluffs to the north, east (and southeast), and south. The survey area also included the Crosswicks Creek floodplain to NJ Route 130 near Yardville, the Delaware River shore from Bordentown to the Trenton boat launch on Lambertson Road, Duck Creek, and terrestrial areas within the wetland and along the bluffs. These areas are contiguous with the wetland itself and comprise an entity that is relatively unaffected by the dense urban development around it. This survey included species from a variety of habitats (see below). The designated area covers nearly 1215 ha, of which about 550 ha are wetlands.

Since the previous study, two new wetlands have been constructed along the Delaware River on Duck Island to compensate for wetland lost during construction of the Trenton Highway Complex and for river edge lost during construction of NJ-129 along the Delaware River in Trenton, NJ. The former, a 38.9 ha site completed in 1994, is the largest New Jersey Department of Transportation wetland mitigation project in New Jersey. It has 32.3 ha of wetlands, of which about 70% are tidal. There are ~ 2 km of channels and eight islands (from northeast to south, island names are D.O.T., Abbott, Dorothy Cross, Elatine, Kalm, Tide Pool, Lenape, and Tiny Islands). For construction and other details see Leck (2003). In 2002, a second 1 ha constructed wetland was completed.

For clarity, the marsh areas will be designated as follows: of the approximately 550 ha of wetlands, 38.9 ha on Duck Is. comprise the 'constructed wetland' (Fig. 1, #17); the remainder will be referred to as the 'pre-existing marsh'. Near the east edge of the pre-existing marsh is located the 'reference marsh' (Fig. 1, #11),

which has been the location of several seed bank studies (e.g., Leck and Graveline 1979, Leck and Simpson 1995). The entire study area, including terrestrial areas, will be referred to simply as the 'Marsh'.

**SITES FOR SEED BANK AND VEGETATION STUDIES.** The reference marsh was a small portion (~ 10 ha) of the 505 ha pre-existing marsh. Its location was chosen for accessibility and because it had representative tidal marsh plant communities (see Whigham and Simpson 1975). It is fed by two shallow (< 2 m) tidal channels and is ~1 km from Crosswicks Creek and ~0.5 km from Watson Creek. The sediments are fine silt and clay that contain as much as 36 % organic material (Simpson et al. 1983, Leck et al. 1988).

In contrast, the constructed wetland has coarse sediments derived from river cobbles, sand, and gravel present at the time of construction. It is linked to the Delaware River by four short (~20 m) inlets lined with riprap. The sampling locations, except that on Elatine Island, were accessible by foot. (See Leck 2003).

**HABITAT TYPES.** *Wetlands.* Wetland communities are varied and include 18 riverine and palustrine communities identified by Whigham and Simpson (1975) (see also Leck et al. 1988). These are found in stream channel, stream bank, high marsh, and tidal pond locations. To these can be added constructed wetlands, non-tidal ponds, such as Spring Lake, and beaver impoundments in former pond-like areas. Beaver, whose activity was first noted in 1996, have had substantial impact raising water level in the pond-like areas near Spring Lake by more than 0.5 m and impeding tidal water flow except during flood tides. Occasionally, flood tides destroy the dams, causing partial and temporary draw-downs.

*Tidal Rivers and Channels.* A number of tidal freshwater rivers define this wetland; these include the Delaware River and Crosswicks, Watson, and Duck Creeks, which have a 2.3 m tidal range. Much of the eastern bank of the Delaware River along the edge of the Marsh has a cobble bottom where certain plant species able to tolerate winter scouring by water and ice, e.g., *Aster puniceus*, *Helianthemum autumnale*, *Lythrum salicaria*, *Vernonia noveboracensis*, and in fewer locations *Justicia americana*, may be found near the high tide line. (For species authorities

see Appendix 1). Below these and also in the intertidal zone, occur *Polygonum punctatum* and *Nuphar lutea*. Rare species such as *Bidens bidentoides* may be found along the upper intertidal cobbles and *Sagittaria subulata* in lower intertidal mudflats. Except for the west bank of Duck Creek (near its mouth), the banks of other rivers are of fine sediments. Where water movement is rapid no macrophytes grow. However, submergent species such as *Ceratophyllum demersum*, *Elodea nuttallii*, *Myriophyllum spicatum*, *Vallisneria americana*, and *Zannichellia palustris* can occur in sizeable beds in Duck Creek, Watson Creek, and the Delaware River. In shallow channels *Nuphar lutea* and *Zizania aquatica* may clog the waterways in summer.

**Ponds.** Sturgeon Pond, Spring Lake, and Rowan Lake (tidal), as well as areas impounded by the highway construction of I-195, I-295, and NJ-129 interchange, and the pond in the Duck Island constructed wetland are to some degree the result of human alteration. For example, Spring Lake, also known as White City Lake, was constructed in the late 19<sup>th</sup> century as part of an amusement park. Since 1996, beaver have created additional impoundments. The ponds are of different ages and depths and have distinctive characteristics. Both Spring Lake and Sturgeon Pond show the effects of hydrological succession. Spring Lake has extensive coverage of *Nuphar lutea* and a fringe of emergents, such as *Lythrum salicaria*, *Peltandra virginica*, *Pontederia cordata*, and *Typha latifolia*. Sturgeon Pond, which was divided in half by highway construction in the 1980s, in contrast, has a broad zone of floating and emergent species with *Ludwigia peploides*, *Nuphar lutea*, *Peltandra virginica*, and *Polygonum amphibium* grading into *Hibiscus moscheutos*, shrubs (e.g., *Viburnum dentatum* and *Alnus* spp.), and trees (e.g., *Acer rubrum*). The tidal Rowan Lake is dominated by *Nuphar lutea*, which is emergent throughout the tidal cycle. Ponds contain submerged and floating macrophytes that do not occur in other wetland types. These include *Nymphaea odorata* (mostly extirpated by 2004), *Ludwigia peploides*, which is infrequent in New Jersey (Hough 1983), and *Proserpinaca palustris*. *Utricularia radiata* and Lemnaceae, including New Jersey rare / endangered species *Wolffella gladiata* and *Lemna valdiviana* (Snyder 1997), have been locally abundant.

**Marshes.** Examples of both tidal and nontidal herbaceous marshes are found within the sur-

vey area. Marshes may be found at the edges of ponds, along tidal channels, or other poorly drained areas. They may be dominated by perennial species, such as *Leersia oryzoides*, *Pontederia cordata*, or *Typha* spp. In 2004 *Phalaris arundinacea* was prominent along the stream channel levee in the reference marsh. Along tidal channels annual species may also seasonally dominate the vegetation (Simpson et al. 1983). These include *Amaranthus cannabinus*, *Ambrosia trifida*, *Polygonum punctatum*, and *Zizania aquatica*. Back from the channel edge the high marsh may be dominated by *Bidens laevis*, *Cuscuta gronovii*, *Impatiens capensis*, and *Polygonum arifolium*, interspersed with perennials, such as *Acorus calamus*, *Peltandra virginica*, and *Schoenoplectus fluviatilis*. In tidal marsh areas, with marked seasonal changes from mud or litter in March, to a carpet of seedlings in April, to vegetation reaching 3 m tall in August, the prodigious growth places these tidal freshwater marshes among the most productive ecosystems in the world (Tiner 1985).

**Shrub Forest Swamps.** Tidal and nontidal shrub forest wetlands that are characterized by woody species occur at the edges of marshes adjacent to terrestrial areas. The thickets of *Alnus incana*, *Alnus serrulata*, *Cephalanthus occidentalis*, *Cornus amomum*, *Ilex verticillata*, and / or *Viburnum dentatum*, with *Acer rubrum* and *Fraxinus pennsylvanica*, occur on hummocks surrounded by marsh. Some shrub forest areas support showy species such as *Aster puniceus*, *Cardamine bulbosa*, *Chelone glabra*, *Lilium canadense*, *Lysimachia ciliata*, and *Rosa palustris*, but where there is a dense canopy these showy species are lacking.

A variant of this habitat are alder swamps, with *Carex stricta* tussocks, other Cyperaceae, *Acer rubrum*, and *Alnus* spp., that are located at the bottom of the bluffs near the C.C. Abbott homestead and along the Crosswicks Creek floodplain near Yardville. Only scattered sedge tussocks have been observed in other areas. This vegetation type may have been historically more extensive; it was documented in a photograph published in the 19<sup>th</sup> C (Abbott 1898). The Abbott swamp site may be compromised both by isolation caused by highway construction and by storm drain runoff.

**Constructed Wetlands.** The constructed wetland, because of its proximity to the Delaware River, openness, and coarse soil that is different from the fine silty soils found elsewhere, has

provided habitat for unusual species, including *Senna hebecarpa* and *Elsholtzia ciliata*. In addition, *Elatine americana* and *Heteranthera multiflora* occurred in shallow 'tide pool' depressions. Woody species, including *Betula nigra*, *Platanus occidentalis*, *Rubus* spp., *Salix* spp. and *Vitis* spp., quickly became established. It has also provided transitory habitat for many other species. Low stature species, such as *Lindernia dubia*, *Ludwigia palustris*, and *Eleocharis acicularis* were replaced by taller species including *Aster puniceus*, *Impatiens capensis*, *Lythrum salicaria*, *Phragmites australis*, and others. See Leck (2003).

The little mitigation site has also provided habitat for opportunistic species, but all have been found in other areas.

**Terrestrial Habitats.** Forests vary in soil type and plant communities they support. West of Spring Lake is a low-lying wooded area dominated by *Acer rubrum* and *Liquidambar styraciflua*. Beaver activity since 1996 has made the area wetter, killing trees whose roots could not tolerate prolonged inundation. Nine species of ferns, including *Botrychium virginianum* and *Woodwardia areolata*, have been found along trails.

Wet woods may also be found on the flood plain of Crosswicks Creek up stream of the Route 206 bridge near Yardville. Tree species there include *Acer negundo*, *Acer saccharinum*, *Fraxinus* spp., *Nyssa sylvatica*, *Platanus occidentalis*, and *Salix* spp. A small stand of mature *Chamaecyparis thyooides* also occurs in this area. Vines of *Vitis* spp., *Menispermum canadense*, *Parthenocissus quinquefolia*, and *Toxicodendron radicans* festoon the trees along the stream and riverbanks. During spring, wildflowers, such as *Claytonia virginica*, *Erythronium americanum*, *Floerkea proserpinacoides*, *Mertensia virginica*, and *Viola* spp., are abundant. *Symplocarpus foetidus* is locally common in seepage areas.

Drier woodlands may be found along the tops of the bluffs, on bluff slopes and on the islands within the pre-existing marsh. They are dominated by *Carya* spp., *Fagus grandifolia*, *Liriodendron tulipifera*, *Quercus* spp., and other hardwood trees. These woods support a variety of wild flowers, such as the spring-blooming *Dicentra cucullaria*, *Podophyllum peltatum*, *Smilacina racemosa*, and *Uvularia sessilifolia*. In open sandy areas in summer, *Chamaecrista nictitans*, *Lespedeza* spp., and *Trichostema dicoto-*

*mum*, as well as native grasses, including *Schizachyrium scoparium* and *Sorghastrum nutans*, can be found. However, once the canopy develops these are lost. Second growth woods can also be observed on Duck Island north of and around the perimeter of the constructed wetland, as well as along the Delaware & Raritan Canal and railroad tracks. There *Robinia pseudoacacia* is common and the rare *Ptelea trifoliata* may occur in open areas

Except for destruction caused by a tornado during late June 1996, relatively undisturbed woods occur on the bluffs along Crosswicks Creek from Point Breeze to the Bordentown Bluffs. These are dominated by *Quercus alba*, *Q. montana*, and *Q. rubra*, with *Liriodendron tulipifera* and *Nyssa sylvatica*. A few trees of *Pinus rigida* and *Tsuga canadensis* also occur there. Unique for this part of New Jersey are dense thickets of *Kalmia latifolia* and *Rhododendron maximum* that dominate the shrub layer.

**Disturbed Areas.** Construction and maintenance activities along roadways, the railroad, sewage treatment plants, and other buildings, as well as places where flotsam is deposited by tides, offer obviously altered and disturbed environments. These occur on a variety of soil types and are places to look for plants that grow in open, often ephemeral habitats. Among the more interesting species found in such places have been *Coreopsis lanceolata*, *Heterotheca subaxillaris*, *Paulownia tomentosa*, and *Vicia tetrasperma*.

Highway construction, which began in 1984, caused considerable disturbance in some areas. Such open places provided a transitory habitat for a variety of species. For example, during a Torrey Botanical Society / Philadelphia Botanical Club trip in September 1990, 12 *Polygonum* species were observed along the road edge (I-195 cloverleaf) at the east edge of the marsh. Several mustards in disturbed areas, including *Camelina microcarpa*, *Diplotaxis tenuifolia*, and *Sisymbrium altissimum*, are infrequent in NJ and have not been previously recorded for Mercer County (Hough 1983).

**Methods.** COMPARISONS OF REFERENCE AND CONSTRUCTED WETLANDS. Comparisons are generally based on examination of published studies: Leck (2003) for the Duck Island constructed wetland and Leck and Graveline (1979), Parker and Leck (1985), Leck et al. (1988) and Leck and Simpson (1987a, b, 1994, 1995) for the ref-

erence marsh. These document the size and composition of the soil seed bank, as well as composition and % cover of the field vegetation. In addition, vegetation changes of the constructed wetland were documented on one of the islands (Elatine) in the following manner. During late summer (14 September 1995, 30 August 1996, 29 August 1997, 28 August 1998, 21 August 1999, 20 / 28 August 2000, 28 August 2001, 13 September 2002, 30 August 2003, 7 September 2004), a 165 m transect was established that extended 30 m into upland areas and 105 m across a tidal marsh saddle with a 30 m perpendicular extension reaching to the closest tidal channel. At 15 m points along the transect 5 m diameter circular plots were marked. Within each plot both common (a subjective estimate of species having the highest densities) and species present were recorded.

**SPECIES SURVEY.** The species list (Appendix 1) is based on plants germinating in soil samples, occurring in field vegetation plots, and/or found during extensive field surveys conducted both on foot and by canoe. It also includes species listed in Leck et al. (1988), and other publications, dating to vegetation studies undertaken by Whigham and Simpson (1975), unpublished data, as well as species observed by J. Arsenault, R. Blicharz, and A. E. Schuyler (including specimens in the A. E. Schuyler Herbarium at the Academy of Natural Sciences of Philadelphia).

Although available 19<sup>th</sup> and 20<sup>th</sup> century lists are incomplete, they provide glimpses of the past flora (Bonaparte 1824, Abbott, 1886, 1887, 1892, 1897, 1898, Shoemaker 1964, 1965). Such species are noted on Appendix 1 or listed in Appendix 2. The Appendix 2 species from Bonaparte, Abbott, and Shoemaker are not included in tallies.

Appendix 3 lists species planted at the constructed wetland. Five, not part of the regional flora (Hough 1983) nor observed elsewhere in the Marsh, are also not included in tallies.

Herbarium specimens for 690 species, maintained at Rider University, have allowed us to check many of our original identifications (Leck et al. 1988). Several listings from the 1988 study that were given only to genus (e.g., *Lilium* sp.), based on vegetative plants, are not included. Of the species listed by Leck et al. (1988), the following are not included here because their accurate identification was questioned: *Berberis vulgaris* (actually *Berberis thunbergii*), *Celastrus scandens* (actually *Celastrus orbiculatus*),

*Desmodium cuspidatum* (likely *Desmodium canadense*), *Euphorbia chamissonis* (actually *Chamaesyce nutans*), and *Pycnanthemum muticum* (likely *Pycnanthemum tenuifolium*).

Generally, nomenclature and authorities follow Rhoads and Klein (1993) and, if a species is not recorded for Pennsylvania, we used Gleason and Cronquist (1991). For *Kyllinga* we used Bryson, et al. (1997). We have changed earlier listings (Leck et al. 1988) to reflect the more recent taxonomy (e.g., *Alliaria officinalis* to *A. petiolata*). To determine modern synonymies for several species given in Bonaparte (1824) and Abbott (1886 1887), we used Gray (1887); in some cases clues came from common names that are still in use. For New Jersey rare or endangered species status designation we used Snyder (1997).

**Results and Discussion.** Our previous study (Leck et al. 1988) provided a hint of the diversity of vascular plant species found in the Marsh with 426 species recorded; here we increase the number to 875 (Appendix 1). The increase can be attributed to: (1) continuing and expanded field exploration, but also (2) the considerable habitat disturbance related to highway construction between 1984–1994 (some of this effect was included in the 1988 report); (3) construction of mitigation wetlands on Duck Island, 38.9 ha in 1994 and 1 ha in 2002, that provided new habitat for many species and (4) location of these constructed wetlands adjacent to the Delaware River that provided a large and diverse seed resource (Leck 2003); and finally (5) increasing the survey area by including the Bordentown Bluffs, Northern Community Park, Delaware & Raritan Canal State Park lands, and other areas, not previously explored, along the floodplains of Crosswicks Creek near Yardville, Duck Creek, and the Delaware River shore. In addition, our comparisons of the reference marsh and constructed wetland provide a view of how disturbance in a wetland system with ample seed dispersal can promote diversity (Tables 1, 2, 3).

We will first consider comparisons between the reference marsh and the constructed wetland. Then we will examine the entire flora and provide some historical notes.

**COMPARISONS OF THE REFERENCE MARSH AND CONSTRUCTED WETLAND.** Numerous comparisons can be made between the constructed wetland and reference marsh, based on seed banks

and vegetation data, that illustrate the high species diversity and colonization potential of tidal freshwater marshes, as well as the importance of rare or endangered and non-native species. The seed bank of the constructed wetland had 177 taxa germinating in soil samples (over 5 years); of these 92 contributed densities  $> 100 / \text{m}^2$  (Table 1; Leck 2003). In contrast, the reference marsh samples contained only 96 species (over 15 years) and 28 taxa had densities exceeding  $100 / \text{m}^2$ . Moreover, of the 101 seed bank species contributing more than 100 seeds  $/ \text{m}^2$ , only 18 were common to both; nine others were found only in the reference marsh and 83 only in constructed wetland samples. A total of 218 seed plant species occurred in seed bank samples; of these 124 occurred only in constructed wetland samples and 34 only in reference marsh ones. In addition, many more Asteraceae, Cyperaceae, and Juncaceae species occurred in constructed wetland than in reference marsh samples (Tables 1, 2; Appendix 1). These distributions suggest dispersal limitations of many seed species.

In contrast to seed plants, more spore-bearing species, seven fern and one horsetail species, grew from reference marsh samples, but only *Onoclea sensibilis* from constructed wetland ones. The lack of other ferns in the constructed wetland samples may be due to limited availability spores, but may also be due to use of tap instead of distilled water for watering and/or to colonization by a greenhouse moss contaminant that could have influenced germination and growth of spore species.

Many more constructed wetland species had high seed bank densities with certain species greatly exceeding the maximum total seed bank values for any reference marsh site (max. =  $64,300 \pm 8,218$  ( $\pm$  SE), Leck and Simpson 1987a) (Table 1). Richness values in the constructed wetland were more than  $2\times$  greater ( $22.9 \pm 1.0$  to  $27.5 \pm 1.7$  species / sample;  $n = 18$ ) than those of the reference marsh ( $5.1 \pm 0.4$  to  $10.8 \pm 0.6$ ) (0–2 cm; March samples; Leck and Simpson 1987a). However, during early succession in the constructed wetland, patterns varied with location; richness values of edge areas did not decrease (Leck 2003), but did on Elatine Island (Fig. 2). This pattern of species richness decline during early succession is similar to that of abandoned agricultural fields (Leck and Leck 1998). Continued high species numbers along edges may be due to water current patterns and

deposition of seed-laden flotsam there (Leck 2003).

Species diversity along hydrologic gradients had different patterns along transects from stream channels to the high marsh. The reference marsh had somewhat higher numbers along the stream channel compared with high marsh locations (Parker and Leck 1985, Leck and Simpson 1994), while in the constructed wetland, numbers were lowest at the channel edge (Leck 2003). In the constructed wetland, especially in the first 2–3 years, there was little persistent plant material near the channel edge to trap seeds, and the tides deposited the seeds well away from the edge. In the reference marsh plants growing on the channel levee likely reduced water flow and, thus, trapped seeds.

Both constructed wetland and reference marsh studies showed that there were typically fewer species in field plots than in seed bank samples. For example, reference marsh field plots contained 24 species, with 18 species contributing to cover, compared to 96 species in soil samples (Leck et al. 1988); the constructed wetland had 92 species in field plots, of which 72 contributed to cover, compared to 177 in soil samples (Leck 2003). These differences between field and greenhouse data may be due to optimal germinating conditions in the greenhouse for more species compared to the field, but also it is also possible that field conditions, such as a coating of mud and high growth rates of other species, were unsuitable for establishment especially of small seedlings.

Overall, the numbers of species contributing to cover were similar with 66 species occurring in the reference marsh plots (all studies) and 72 species in the constructed wetland. Composition, however, was not similar. In the reference marsh, depending on location relative to the tidal channel, dominants were *Acorus calamus*, *Bidens laevis*, *Impatiens capensis*, *Peltandra virginica*, *Polygonum arifolium*, and *Typha latifolia* (all species having  $> 10\%$  cover; Leck and Simpson 1987a, 1995), as well as *Amaranthus cannabinus*, *Nuphar lutea*, *Polygonum punctatum*, and *Sagittaria latifolia* ( $> 5\%$  relative density or cover; Parker and Leck 1985). Most of these reference marsh species were absent as cover species during early succession from the constructed wetland; instead *Aster puniceus*, *Juncus effusus*, *Lindernia dubia*, *Ludwigia palustris*, *Lythrum salicaria*, *Mimulus* spp., and *Penthorum sedoides* were important (Table, 1; Leck 2003). Furthermore, the constructed wetland

Table 1. Seed bank species contributing  $> 100/m^2$  in reference (RM) and constructed wetland (CW) studies\*. Data are maximum mean densities ( $\pm$  SE). For the constructed wetland seed bank frequencies are also given and are based on four years, three sites and three locations ( $n = 36$ ). (Overall, total species numbers were: RM = 95, CW = 183; RM + CW = 218, with 34 in RM only and 60 in both).

Species	Density (Mean $\pm$ SE)	Freq. (%)
REFERENCE MARSH (28 taxa)		
<i>Amaranthus cannabinus</i>	3,675 $\pm$ 1,044	
<i>Ambrosia trifida</i>	119 $\pm$ 42	
<i>Bidens laevis</i>	1,690 $\pm$ 554	
<i>Boehmeria cylindrica</i>	>100	
<i>Callitriche heterophylla</i>	915 $\pm$ 401	
<i>Cardamine pensylvanica</i>	500 $\pm$ 397	
<i>Carex</i> spp. (3)	280 $\pm$ 136	
<i>Cuscuta gronovii</i>	4,830 $\pm$ 2,390	
<i>Dulichium arundinaceum</i>	1,040 $\pm$ 560	
<i>Eupatorium dubium</i>	180 $\pm$ 106	
<i>Gratiola neglecta</i>	>100	
<i>Impatiens capensis</i>	2,080 $\pm$ 315	
<i>Juncus effusus</i>	1,280 $\pm$ 731	
<i>Leersia oryzoides</i>	190 $\pm$ 158	
<i>Mikania scandens</i>	8,360 $\pm$ 1,636	
<i>Nuphar lutea</i>	120	
<i>Peltandra virginica</i>	141 $\pm$ 80	
<i>Phalaris arundinacea</i>	3,433 $\pm$ 3,433	
<i>Pilea pumila</i>	6,350 $\pm$ 1,524	
<i>Poa trivialis</i>	2,540 $\pm$ 1,944	
<i>Polygonum arifolium</i>	2,415 $\pm$ 524	
<i>Polygonum punctatum</i>	1,475 $\pm$ 591	
<i>Polygonum sagittatum</i>	140	
<i>Ranunculus sceleratus</i>	320 $\pm$ 287	
<i>Sagittaria latifolia</i>	425 $\pm$ 115	
<i>Sium suave</i>	125 $\pm$ 73	
<i>Typha latifolia</i>	53,000 $\pm$ 7,445	
<i>Zizania aquatica</i>	163 $\pm$ 138	
CONSTRUCTED WETLAND (100 taxa)		
<i>Agrostis perennans</i>	183 $\pm$ 183	2.8
<i>Alisma plantago-aquatica</i>	100 $\pm$ 100	5.6
<i>Amaranthus cannabinus</i>	985 $\pm$ 602	44.4
<i>Artemisia vulgaris</i>	200 $\pm$ 113	25
<i>Arthraxon hispidus</i>	933 $\pm$ 856	66.7
<i>Aster pilosus</i>	1,633 $\pm$ 848	63.1
<i>Aster puniceus</i>	10,300 $\pm$ 2,471	50
<i>Aster</i> spp.	1,833 $\pm$ 164	22.2
<i>Bidens connata</i>	150 $\pm$ 50	19.4
<i>Bidens frondosa</i>	550 $\pm$ 263	44.4
<i>Bidens laevis</i>	4,617 $\pm$ 2,308	61.1
<i>Boehmeria cylindrica</i>	3,243 $\pm$ 737	69.4
Brassicaceae	185 $\pm$ 153	27.8
<i>Carex</i> (I)	617 $\pm$ 368	66.7
<i>Carex</i> (II)	514 $\pm$ 481	30.6
<i>Carex</i> (III)	414 $\pm$ 351	50
<i>Carex frankii</i>	150 $\pm$ 150	11.1
<i>Carex lurida</i>	133 $\pm$ 133	5.6
<i>Carex scoparia</i>	1,350 $\pm$ 1,105	22.2
<i>Carex</i> spp.	666 $\pm$ 523	19.4
<i>Carex stipata</i>	1,350 $\pm$ 1,350	8.3
<i>Carex stricta</i>	135 $\pm$ 135	2.8
<i>Carex tribuloides</i>	350 $\pm$ 212	19.4
<i>Carex vulpinoidea</i>	116 $\pm$ 116	22.2
<i>Cephalanthus occidentalis</i>	100 $\pm$ 37	13.9
<i>Chenopodium ambrosioides</i>	1,686 $\pm$ 386	75
<i>Cicuta bulbifera</i>	100 $\pm$ 63	8.3

Table 1. Continued.

Species	Density (Mean $\pm$ SE)	Freq. (%)
<i>Cuscuta gronovii</i>	1,883 $\pm$ 324	30.6
<i>Cyperus bipartitus</i>	7,250 $\pm$ 2,879	58.3
<i>Cyperus diandrus</i>	267 $\pm$ 158	13.9
<i>Cyperus erythrorhizos</i>	1,971 $\pm$ 963	50
<i>Cyperus lupulinus</i>	166 $\pm$ 148	16.7
<i>Cyperus flavescens</i>	616 $\pm$ 617	13.9
<i>Cyperus odoratus</i>	2,617 $\pm$ 863	2.8
<i>Cyperus strigosus</i>	3,486 $\pm$ 637	80.6
<i>Cyperus</i> spp.	850 $\pm$ 540	38.9
<i>Digitaria filiformis</i>	128 $\pm$ 89	8.3
<i>Digitaria ischaemum</i>	133 $\pm$ 49	25
<i>Echinochloa crusgalli</i>	3,017 $\pm$ 1,878	77.7
<i>Eclipta prostrata</i>	542 $\pm$ 76	55.6
<i>Eleocharis acicularis</i>	11,200 $\pm$ 10,000	16.7
<i>Eleocharis erythropoda</i>	133 $\pm$ 133	8.3
<i>Eleocharis obtusa</i>	4,583 $\pm$ 2,120	77.8
<i>Eleocharis</i> spp.	166 $\pm$ 166	16.7
<i>Erigeron annuus</i>	1,183 $\pm$ 596	11.1
<i>Eupatorium perfoliatum</i>	3,183 $\pm$ 1,571	33.3
<i>Eupatorium serotinum</i>	150 $\pm$ 62	47.2
<i>Euthamia graminifolia</i>	283 $\pm$ 125	27.8
<i>Gratiola neglecta</i>	17,316 $\pm$ 4,222	75
<i>Helenium autumnale</i>	983 $\pm$ 887	47.2
<i>Hypericum mutilum</i>	2,400 $\pm$ 1,875	69.4
<i>Impatiens capensis</i>	583 $\pm$ 214	38.8
<i>Juncus acuminatus</i>	14,120 $\pm$ 6,651	86.1
<i>Juncus effusus</i>	39,967 $\pm$ 20,311	75
<i>Juncus tenuis</i>	12,400 $\pm$ 8,290	75
<i>Juncus</i> spp.	7,017 $\pm$ 4,081	50
<i>Leersia oryzoides</i>	2,550 $\pm$ 1,175	77.8
<i>Lemna minor</i>	752 $\pm$ 752	8.3
<i>Lindernia dubia</i>	172,214 $\pm$ 23,235	97.2
<i>Ludwigia alternifolia</i>	117 $\pm$ 83	13.9
<i>Ludwigia palustris</i>	258,610 $\pm$ 34,080	97.2
<i>Lycopus americanus</i>	1,050 $\pm$ 665	30.6
<i>Lycopus europaeus</i>	750 $\pm$ 243	27.8
<i>Lycopus virginicus</i>	150 $\pm$ 72	19.4
<i>Lycopus</i> spp.	6,016 $\pm$ 4,177	58.3
<i>Lythrum salicaria</i>	207,900 $\pm$ 30,760	88.9
<i>Microstegium vimineum</i>	666 $\pm$ 539	50
<i>Mikania scandens</i>	4,757 $\pm$ 3,102	16.7
<i>Mimulus ringens</i> (+ <i>alatus</i> )	4,767 $\pm$ 2,560	92.7
<i>Mollugo verticillata</i>	550 $\pm$ 347	38.9
<i>Oenothera biennis</i>	250 $\pm$ 56	36.1
<i>Panicum dichotomiflorum</i>	2,333 $\pm$ 2,095	75
<i>Panicum</i> spp.	267 $\pm$ 193	19.4
<i>Penthorum sedoides</i>	6,150 $\pm$ 1,819	86.1
<i>Phalaris arundinacea</i>	1,133 $\pm$ 1,133	47.2
<i>Phragmites australis</i>	133 $\pm$ 133	27.8
<i>Pilea pumila</i>	14,900 $\pm$ 4,849	72.2
<i>Platanus occidentalis</i>	117 $\pm$ 65	16.7
<i>Poa trivialis</i>	133 $\pm$ 114	8.3
<i>Polygonum arifolium</i>	128 $\pm$ 57	(+)
<i>Polygonum caespitosum</i>	883 $\pm$ 289	86.1
<i>Polygonum hydropiper</i>	1,733 $\pm$ 870	61.1
<i>Polygonum hydropiperoides</i>	883 $\pm$ 472	66.7
<i>Polygonum lapathifolium</i>	1,167 $\pm$ 632	77.8
<i>Polygonum pensylvanicum</i>	883 $\pm$ 313	83.3
<i>Polygonum persicaria</i>	117 $\pm$ 117	19.4

Table 1. Continued.

Species	Density (Mean $\pm$ SE)	Freq. (%)
<i>Polygonum punctatum</i>	8,933 $\pm$ 2,453	83.3
<i>Polygonum setaceum</i>	220 $\pm$ 120	30.6
<i>Polygonum</i> spp.	1,500 $\pm$ 664	50
<i>Potentilla norvegica</i>	3,117 $\pm$ 1,154	80.6
<i>Sagittaria latifolia</i>	2,300 $\pm$ 803	47.2
<i>Schoenoplectus smithii</i>	300 $\pm$ 300	27.8
<i>Scirpus cyperinus</i>	173 $\pm$ 173	2.8
<i>Scutellaria epilobiifolia</i>	200 $\pm$ 113	19.4
<i>Scutellaria lateriflora</i>	133 $\pm$ 67	27.8
<i>Sium suave</i>	167 $\pm$ 80	11.1
<i>Solidago canadensis</i>	650 $\pm$ 422	44.1
<i>Solidago rugosa</i>	100 $\pm$ 68	38.9
<i>Typha</i> spp.	7,100 $\pm$ 7,078	50
<i>Verbascum thapsus</i>	285 $\pm$ 184	25
<i>Verbena hastata</i>	283 $\pm$ 245	22.2
<i>Veronica peregrina</i>	1,050 $\pm$ 637	38.8

\* Data are from Leck and Graveline (1979), Parker and Leck (1985), Leck and Simpson (1987a, 1994, 1995) for the reference marsh, and Leck (2003) for the constructed wetland, and unpublished data.

cover species, except for *Gratiola neglecta*, were found only occasionally or not at all in the reference seed bank samples over 15 years (Leck and Simpson 1987a, 1994, 1995, Leck et al. 1988).

Certain reference marsh dominants occurred in the constructed wetland, but varied in their colonization potential. Two, *Bidens laevis* and *Polygonum punctatum*, were common during the first year (Leck 2003). With time, however, *Impatiens capensis* and *Cuscuta gronovii* became more important in the vegetation; so that after four years *Impatiens capensis* occurred in 93 % of upland edge plots, with cover averaging 33.5  $\pm$  6.4 % ( $n = 27$ ), and in 62 % of the plots ( $n = 13$ ) on Elatine Island. *Cuscuta gronovii* occurred in 26 % of the cover plots (contributing to cover only in 7 % of the plots with maximum cover of 5 %;  $n = 27$ ) and in 38 % of plots on Elatine Island.

In addition to these density and diversity comparisons, vegetation structure and morphology differed. Colonization of the constructed wetland was by many low-growing species. Taller species quickly became established contributing to a layered community (Leck 2003). The reference marsh did not demonstrate layering because nearly all species were capable of tall and/or viney growth (Leck and Simpson 1995). Field production of pseudo-viviparous plantlets occurred only in the constructed wetland. Also, the colonizing dominant species of the constructed wetland (1995–1999) had smaller seed sizes (0.01–3.2 mg;  $n = 8$ ) than those of the reference marsh (0.01 to 530 mg;  $n = 19$ ). The large seeds

of the reference marsh are associated with transience, where a sizable component of seed bank lasts < 1 yr in the soil, while small seeds, characteristic of the constructed wetland, are persistent and last > 1 yr (Leck and Simpson 1987a, 1995; Leck and Brock 2000).

Particular groups, such as rare or endangered and non-native species, differed between wetlands. During the early colonization period, more rare or endangered species occurred in the constructed wetland; soil samples of the reference marsh contained only one rare species compared with eight in constructed wetland samples (Table 3). Some, such as *Isoetes riparia*, were scarce and transitory, with only a few plants found during a single growing season.

Non-native species comprised 9 % of the seed bank species in the reference marsh and 13 % in the constructed wetland, and 8 and 12 %, respectively, of the cover species. These percentages are low compared to other wetland studies (e.g., Magee et al. 1999) reflecting the need for wetland specialist species that are able to tolerate, for example, variable tidal inundation regimes and rapid growth of other species (see Aznar et al. 2003). Of the invasive non-native species considered to be problems in wetlands, *Lythrum salicaria*, *Phalaris arundinacea*, and *Phragmites australis* were more important in both the seed bank and vegetation of the constructed wetland (Table 1; Appendix 1) and did not appear in the reference marsh vegetation plots (Leck and Simpson 1994, 1995) although *Phalaris arundinacea* did establish along the channel levee (MAL pers. observ.). In the con-

Table 2. Vascular plant summaries for the Hamilton-Trenton-Bordentown Marsh. A. Phyla summaries. B. Species distribution among families having the highest richness (see Appendix 1). Shown are: family species totals, species having special designation (e.g., rare or endangered; Snyder 1997), non-natives species, and species distributions for seed banks (sb) of both the reference marsh (RM) and constructed wetland (CW) and for field cover (f) of the constructed wetland. The percents of family totals are also given.

Lycopodiophyta &										
A.	Equisetophyta	Psittacophyta	Pinophyta	Magnoliopsida	Liliopsida	Total				
Families	4	7	3	103	22	141				
Genera	5	14	6	311	105	443				
Species	7	21	7	580	260	875				
Non-native species	0	0	1	181	55	236				
B.	FAMILY	Total spp.	Special spp.	% of total	Nomative spp.	% of total	RM sb spp.	CW sb spp.	CW f spp.	CW f % total
Asteraceae	103	5	4.9	28	27.2	13	29	70	70	
Poaceae	100	1	1	37	37	13	23	53	53	
Cyperaceae	83	3	3.6	2	2.4	6	33	58	69.9	
Fabaceae	33	0	0	19	57.6	0	4	22	66.7	
Lamiaceae	30	4	13.3	9	30	2	7	19	63.3	
Rosaceae	29	0	0	8	27.6	2	2	11	37.9	
Polygonaceae	25	1	3.8	10	40	3	13	22	88	
Brassicaceae	22	0	0	13	59	2	3	11	50	
Scrophulariaceae	20	1	5	8	40	3	5	16	80	
Liliaceae	17	0	0	7	41.2	0	0	5	29.4	
Caryophyllaceae	16	1	6.7	10	62.5	0	1	12	75	
Salicaceae	15	1	6.3	3	20	4	1	4	26.6	
Fagaceae	13	0	0	0	0	2	0	1	7.7	
Apiaceae	12	0	0	3	25	2	3	4	33.3	
Ranunculaceae	10	1	10	4	40	2	1	6	60	
Dryopteridaceae	9	0	0	0	0	3	1	2	22.2	
Juncaceae	9	2	22.2	0	0	2	3	7	77.8	
Rubiaceae	9	0	0	0	0	1	2	5	55.5	
Betulaceae	8	0	0	1	12.5	3	2	2	25	
Caprifoliaceae	8	0	0	3	37.5	2	0	2	25	
Ericaceae	8	0	0	0	0	0	0	0	0	
Onagraceae	7	0	0	0	0	2	4	5	71.4	
Lemnaceae	6	2	0	0	0	1	1	2	33.3	
Subtotals	592	22	168	236	68	339	138	465	53.1	
Totals	875	37	4.2	236	27	117	177	465	53.1	

Table 3. New Jersey rare or endangered species (Snyder 1997) recorded for the Hamilton–Trenton–Bordentown Marsh. Global and state rankings\* are given. Species are designated as occurring in the reference marsh, constructed wetland, entire study area (Marsh), or as a herbarium record. Species located nearby study plots are '(+)'. Species designated as 'T' occurred in terrestrial locations. Herbarium species are located in the A.E. Schuyler Herbarium of the Academy of Natural Sciences of Philadelphia. (From Leck et al. 1988, Leck 2003, and unpublished).

Species	Reference marsh	Constructed wetland		Marsh	Herbarium record only
	Seed bank	Seed bank	Vegetation		
<i>Agastache nepetoides</i> (G5, S2)*				T	
<i>Agastache scrophulariifolia</i> (G4, S2)				T	
<i>Andropogon ternarius</i> (G5, S2)			T		
<i>Aster longifolius</i> (G5, S1, E)				+	
<i>Bidens bidentoides</i> (G3, S2, E)		+	(+)	+	
<i>Cacalia atriplicifolia</i> (G4-5, S1, E)				T	
<i>Carex frankii</i> (G5, S3)		+	(+)T	+	
<i>Carex sterilis</i> (G4, S2)		+	(+)		
<i>Cuscuta polygonorum</i> (G5, S2)			(+)		
<i>Cyperus retrofractus</i> (G5, SH, E)				T	
<i>Elatine americana</i> (G4, S2)			(+)		
<i>Eriocaulon parkeri</i> (G3, S2)					+
<i>Eupatorium altissimum</i> (G5, S2)				T	
<i>Eupatorium aromaticum</i> (G4-5, S1)				T	
<i>Euphorbia corollata</i> (G5, S2)				T	
<i>Heteranthera multiflora</i> (G4, S2)		+?	(+)	+	
<i>Isoetes riparia</i> (G4, S3)			(+)		
<i>Juncus brevicaudatus</i> (G5, S2)			(+)		
<i>Juncus torreyi</i> (G5, S1)			(+)		
<i>Lemna valdiviana</i> (G5, S1, E)				+	
<i>Lycopus rubellus</i> (G5, S2)		+	(+)		
<i>Mimulus alatus</i> (G5, S3)		+?	(+)	+	
<i>Myriophyllum heterophyllum</i> (G5, S2)					+
<i>Nelumbo lutea</i> (G4, S1, E)					+
<i>Polygonum setaceum</i> (G5, S2)		+	(+)		
<i>Populus heterophylla</i> (G5, S2)	+			+	
<i>Ptelea trifoliata</i> (G5, S1, E)			T	T	
<i>Quercus michauxii</i> (G5, S3)				+	
<i>Ranunculus longirostris</i> (G5, S2)					+
<i>Sagittaria subulata</i> (G4, S2)			(+)	+	
<i>Schoenoplectus smithii</i> (G5?, S2)		+	(+)		
<i>Scirpus atrocinctus</i> (G5, S1)			(+)		
<i>Silene caroliniana</i> (G5, S3)				T	
<i>Tradescantia ohioensis</i> (G5, S2)				T	
<i>Utricularia gibba</i> (G5, S3)				+	
<i>Utricularia intermedia</i> (G5, S3)					+
<i>Wolffiella gladiata</i> (G?, S1, E)				+	
Totals: 37	1	6 (8)	17	21	5

\* Ranking (Snyder 1997): Global (G1–5); G1 = critically imperiled globally to G5 = demonstrably secure globally although possibly rare at the periphery of range; State (S1–5); S1 = critically imperiled in New Jersey to S5 = demonstrably secure in the state under present conditions. SH = of historical occurrence in New Jersey, but no extant populations known. E = endangered, prospects for survival in New Jersey are low and the species is in immediate danger.

structed wetland, both on upland edge sites (Liscko unpublished) and along the study transect on Elatine Island, *Lythrum salicaria* did not reduce species richness of the vegetation and, in fact, *Lythrum salicaria* itself declined after three years (Fig. 2). *Phragmites australis*, as it continues to expand like it has in other wetlands (Rice et al. 2000), may have the greatest and continuing impact. After five years (in 1999) along tran-

sects (channel edge, midpoint, and upland edge locations), vegetation frequencies were 0, 0, and 33 %, respectively; after 10 years (2004) they were 0, 44, and 67% ( $n = 9$ ; Leck 2003 and unpublished data). In some locations, however, stands are not monospecific and *Phragmites australis* co-occurs with other species, such as *Impatiens capensis* and *Mikania scandens*.

Population dynamics of these constructed

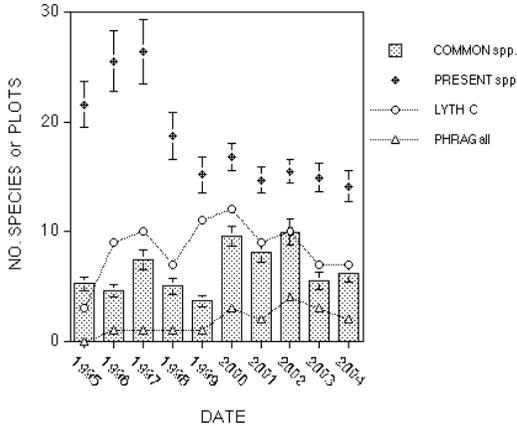


FIG. 2. Species richness on Elatine Island and occurrences of invasive species. Data are numbers of common (bars) or present (black diamonds) species (mean  $\pm$  SE) per plot. Also shown are the number of plots in which *Lythrum salicaria* was common (open circles) and all plots in which *Phragmites australis* was found (triangles). ( $n = 13$ ; plots 5 m radius).

wetland invasive species differed. *Lythrum salicaria* waxed and waned, but continued to contribute to the vegetation (Fig 2). Overall, *Phragmites australis*, as noted above, appears to be increasing although data from Elatine Is. (Fig. 2) do not appear to indicate this. In contrast, *Phalaris arundinacea*, present mainly at upland edges, was not found along study transects in 2004 (unpublished data).

Many factors contribute to the differences between the reference marsh and the constructed wetland. These include reduced dispersal, related to the relative isolation of the reference marsh, which receives water from two small meandering tidal channels connected to Crosswicks and Watson Creeks. For the constructed wetland the Delaware River (Fig. 1) was nearby and was the source of flotsam that was  $> 10$  cm deep in many places and that contained large numbers of diverse seeds (MAL pers. observ.). In addition to dispersal, conditions for establishment, although not fully understood, are involved. It is apparent that many species exploited the open niches associated with early successional habitats following dispersal into the constructed wetland (Tables 1, 3; Fig.1). Such species were not able to tolerate increased competition as the vegetation developed and species of low stature were replaced by taller ones (Leck 2003).

Sediment differences may also contribute to establishment and seed bank patterns. For example, roots of *Peltandra virginica*, one of the reference marsh dominants (Leck and Simpson

1995), cannot penetrate consolidated, compacted sediment (Garbisch 1994). In addition, wetland species are known to have variable germination responses to soil texture (Keddy and Constabel 1986, Weiher et al. 1996) and to sedimentation (Ditmar and Neely 1999).

Another kind of comparison when evaluating the success of replacement wetlands, is whether constructed and reference marshes are equivalent. Studies from other locations have shown variable success (e.g., Bishel-Machung et al. 1996, Goldman-Carter and McCallie 1996, Galatowitsch and van der Valk 1996, Wilson and Mitsch 1996, Whigham 1999, Zedler and Callaway 1999, Klotzli and Grootjans 2001). Also, although vegetation structure and seed banks may be different from those of reference wetlands, constructed wetlands can provide community level information about seed banks and vegetation processes, including seed dispersal patterns (Cappers 1993, Cain et al. 2000). They can also be used to assess vegetation structure and dynamics of constructed / restored versus reference wetlands (Baldwin and DeRico 1999, Ehrenfeld 2000). Here, in the short time the constructed wetland was monitored, the species-rich nature of tidal freshwater marshes (Simpson et al. 1983) was achieved, but species composition and structure were not similar (Table 1; Leck 2003).

Thus, although the constructed wetland and reference marsh did not have similar seed bank densities, seed bank and vegetation species richness, or species composition, these comparisons provide several insights. First, anthropogenic manipulations and associated habitat diversification provided establishment habitats for many species, including rare ones not found elsewhere in the Marsh. Second, colonizing (early successional) species of the constructed wetland had high levels of *in situ* seed production, resulting in much higher densities and species richness values than those found in the reference marsh. Finally, although numbers of non-native (and invasive) species were a relatively small component of the seed bank and vegetation for both sites (8–13 %), their importance in the constructed wetland seed bank and vegetation was far greater.

**SPECIES SURVEY.** To date (September 2004), we have recorded 875 species, including 148 (16.9 %) woody and 236 (27 %) alien species (Appendix 1). Thirty-seven (4.2 %) are worthy of note as species that require conservation con-

cern in New Jersey; of these, eight (0.9 %) are designated as endangered (Table 3; Snyder 1997). Parenthetically, 268 of these species were not recorded for Mercer County by Hough (1983). The families having the greatest numbers of species are presented in Table 2. Overall, 141 families were recorded; 11 were ferns and fern allies, 3 Pinophyta, and 125 Magnoliophyta, the latter comprised of 103 Magnoliopsida and 22 Liliopsida families. In the constructed wetland, species of certain families (Table 2 B), e.g., Polygonaceae (88 %), Scrophulariaceae (80 %), and Juncaceae (77.8 %), exceeded 70 % of the total species for that family. In contrast, Fagaceae (7.6 %) and Ericaceae (0 %) were not important at the constructed wetland. In a recent evaluation of 70 geographically diverse seed bank studies, Leck and Schutz (2005) found the highest Cyperaceae diversity in constructed wetland samples (Leck 2003). Eight genera provided > 10 species (*Carex* 46, *Polygonum* 19, *Cyperus* 13, *Eupatorium* 13, *Panicum* 12, *Bidens* 11, *Quercus* 11, *Salix* 10). Eleven were errant or planted ephemerals (end Appendix 1).

Few species were documented from soil seed bank samples (Leck et al. 1988, Leck 2003) that were not also found in the field. These included: *Cyperus squarrosus*, *Drosera rotundifolia*, *Hedeoma pulegioides*, *Plantago major*, *Polygonum careyi*, *Salix bebbiana*, *Salix* hybrid, and *Woodwardia virginica*.

Examination of herbarium specimens revealed nine species, *Cyperus bipartitus*, *C. flavescens*, *Eleusine indica*, *Juncus acuminatus*, *Poa trivialis*, *Scirpus atrovirens*, *Scirpus georgianus*, *Scirpus polyphyllus*, and *Schoenoplectus purshianus*, that produced pseudo-viviparous plantlets on inflorescences. Except for *Cyperus bipartitus* and *Poa trivialis*, all were collected from the field.

In addition to those that dispersed into the site, 37 species were planted as part of the landscaping provided for the Duck Island constructed wetland (NJDOT 1996) (Appendix 3). Planting certainly helped initiate colonization. There were at least two instances, *Pontederia cordata* and *Sagittaria latifolia*, where established planted plants provided a seed source for new seedlings (pers. observ.); only *Sagittaria latifolia* was found in seed bank samples (Appendix 1). However, contributions of the planted species to the seed bank and vegetation were small because so many other species grew there (Leck 2003). In fact, *Peltandra virginica*, *Pontederia cordata*, and *Sagittaria latifolia*, likely from seeds, were

already present in 1994 (Leck 2003). Of the species listed for planting, we did not observe *Zizania aquatica* seedlings in 1995, but it was well established by 1998. Woody species appeared to have fared the worst, generally because other species, such as *Robinia pseudoacacia*, established and grew quickly, overtopping them. Planted *Acer rubrum* and *Sambucus canadensis* in some locations died or were stunted and chlorotic, apparently due to improper location. Terrestrial areas, especially on islands, could be too dry in summer and too wet during winter flooding, reducing establishment. Planted macrophytes persisted at least until 1998, when after four years it was often not possible to distinguish plantings from the surrounding vegetation.

The 875 species that are reported here for the Marsh reflect the temporal and spatial diversity of habitats. The occurrence of 37 rare or endangered species, 11 of which occurred only in the constructed wetland (Table 3), also indicates the importance of having varied habitats, including those with low fertility and low competition. The diverse habitats, briefly described above, may be predictable, e.g., the reference marsh, with regular tides and no seasonal drying (Leck and Brock 2000) or unpredictable, e.g., sand bars and the constructed wetland, where substrate or quality of establishment niches change. Among habitats, there are also dynamic and variable stresses (Table 4), with physical stresses being more important along stream channels and biotic stresses on the high marsh (Parker and Leck 1985). Along tidal channels the scouring that occurred during winter removed all standing dead plant material. In the constructed wetland tidal deposition of wrack, coming from the nearby Delaware River, caused death of plants and created open patches for colonization. Wrack deposition was not a noticeable feature of other marsh areas.

Factors contributing to high diversity include effective dispersal, maintenance of 'normal' levels of disturbance that involve, e.g., plant replacement (annuals), ice impacts in winter, sediment deposition, etc., and changes in communities due, for example, to population dynamics (Leck and Simpson 1995). Also, as noted above, wetland creation and associated disturbance provided niches for many species. Reduction in diversity would come from inability of specialized species to tolerate the changes. In some cases, invasives may themselves be the disturbance, reducing diversity. While *Lythrum salicaria*, was not observed to reduce diversity in the con-

Table 4. Non-anthropogenic and anthropogenic stresses and main effects on tidal freshwater wetland vegetation.

Stresses	Main effects
<i>Non-anthropogenic</i>	
Disturbance (litter/wrack, storms, animals)	seed dispersal, seed rain, germination, recruitment
Tide period & range (hydrology)	germination, recruitment
Biotic competition	Δ recruitment, establishment
<i>Anthropogenic</i>	
Climate change	T°—germination, establishment
Sea level rise	communities change position along gradient; some communities lost locally
Nutrients	> growth, > biotic stress, > rate of germination (some species)
Pollutants (e.g., pH: pesticides, oil, metals)	recruitment, growth; indirect: herbivores, pollinators
Invasive plant species	< diversity, Δ seed rain patterns, availability of seeds
Habitat fragmentation	dispersal & seed rain patterns
Sedimentation	germination, recruitment, growth

structed wetland (Fig. 1; Lisco unpublished data), expansion of *Phragmites australis* eliminated species of low stature.

*Looking Ahead.* Successional changes will continue to occur at the constructed wetland for some time. It is also anticipated that future changes to the entire wetland complex will largely be anthropogenically induced. Orson et al. (1992) illustrate the considerable and continuing human influence on marsh development as sea level rise and high sedimentation rates, related to land use practices, support sediment levels conducive to tidal marsh communities. At the present time in the constructed wetland, sediment is accumulating in channels where water flow is slow. In addition, climate change, pollutants (salts and other materials from highways and storm drains), establishment of exotics and invasives, management decisions, and habitat fragmentation will affect wetland and terrestrial communities. Table 4 indicates some of the main effects of various stresses on wetland plants. These impacts are often subtle, but may be dramatic.

While species diversity, as represented by the total number of species found at the Marsh, indicates high quality of ecosystems, watershed level management decisions are being made that may have significant (negative?) impact on the Marsh. Following storms, for example, there is continuing high sediment load in Crosswicks Creek related to watershed development. This study should serve as a baseline against which to evaluate future anthropogenic impacts as well as natural (e.g., successional) changes.

One of the most notable features of the con-

structed wetland was its substantial contribution to species diversity (Tables 1–3, Appendix 1). However, extirpation of populations elsewhere could limit influx of propagules.

**SOME HISTORICAL NOTES.** Glimpses of the former botanical landscape are provided by Charles Lucien Bonaparte (1824), by Dr. Charles Conrad Abbott who wrote extensively about the area around his home in the 19<sup>th</sup> century (e.g., Abbott 1887), and by Lois Shoemaker (1964, 1965). In addition to his own observations, Abbott provides a summary of those by Peter Kalm who in 1749 wrote about the plants he encountered as he traveled by boat from Philadelphia to Trenton and then to New York City by stage. Kalm reported that the forests near Trenton contained an “abundance of chestnut-trees”, and tulip-trees had replaced other species that had been abundant during the previous century. He also observed that,

“the beaver-tree (*Magnolia virginiana*) grows in the swamps. It is now (June 1st) in flower, and the fragrancy of its blossoms has so perfumed the air that one could enjoy it before one approached the swamps; and this fine smell likewise showed that a beaver-tree was near us, though we did not happen to see it” (p. 147).

Abbott (1887) concurred with Kalm, finding evidence in local documents indicating that magnolias had been more common two centuries before. Today sweet bay magnolia is infrequent, but there is a sizable tree at the north edge of Abbott’s swamp. Regarding the other tree species mentioned, chestnuts are now infrequent

due to chestnut blight. Tulip trees, in contrast, and as noted by Kalm and Abbott, are still common and several large trees may be found along the bluffs at Northern Community Park (Fig. 1).

Some of Abbott's other observations include his standing "in the midst of many acres" of bluets (*Hedyotis caerulea*), at a density of 16 per square inch (Abbott 1887). He also wrote "In an old woodland I once traced a fence by the long line of cyripediums in bloom, which were thriving in the mould of decayed fence-rails" (Abbott 1898; p. 196). Golden club (*Orontium aquaticum*) and lotus (*Nelumbo lutea*) were the two rarest plants (Abbott 1898). Similarly, we have observed dense patches, but not acres, of bluets in the Watson Woods picnic area and know of only about a dozen golden club plants on the banks of Crosswicks Creek, perhaps in the same location where Abbott observed this species. The lotus is no longer extant, but there is a locally obtained specimen at the Academy of Natural Sciences of Philadelphia. Today lady slippers (*Cypripedium acaule*) appear to be scarce and we have seen only five single and widely scattered non flowering plants although Bordentown residents reported having seen large numbers in flower during the past 30 years (Jan Bisco Werner, pers. com.).

Shoemaker (1964, 1965) also reported a number of species for Roebbling Memorial Park and Charles Abbott's homestead, called Three Beeches. For the latter, she noted honeysuckle, the three beeches for which the property was named, a solitary white pine, as well as myrtle, daylilies, cultivated strawberries, hearts-ease (*Viola tricolor* L.), and apple trees near the foundation of the Abbott house cellar hole.

The available lists of Bonaparte, Abbott, and Shoemaker and herbarium records indicate a loss or decline of a number of species (Appendix 2, Table 3). For example, *Nelumbo lutea* and *Saxifraga virginensis* are no longer present, and *Aquilegia canadensis* is found only on the rocks of the grotto at Point Breeze.

### Conclusions.

1. We have doubled the number of species reported in our 1988 inventory, suggesting that many still await discovery. It is our hope that the marshlands and surrounding terrestrial habitats will continue to inspire botanical exploration.
2. Comparisons of reference and constructed wetlands have contributed insights regarding the positive impact of human landscape manipulation on plant species diversity in a tidal freshwater system.
3. The constructed wetland and little mitigation site contributed many species not (yet) found elsewhere.
4. Many species were transitory in the constructed wetland where microhabitats changed quickly during succession.
5. Large areas, including terrestrial habitats, are critical to estimating and preserving species richness; several species occurred in a single location.
6. The constructed wetland, at least in its first years, provided habitat for numerous species, including a number of rare ones that favor open, disturbed habitats. However, as succession proceeds and as *Phragmites australis* expands its coverage, we predict open habitat and species of low stature will be further reduced.
7. Continuing disturbance is key to providing habitat for colonizing species, species of low stature, and rare species, and for maintaining diversity.
8. Water is an effective dispersal agent for many species, but many other wetland species appear to have restricted distribution.
9. Historical records, however incomplete, provide clues to environmental change.
10. We expect that anthropogenic influences will continue to modify habitats and affect plant species establishment. We hope that management and open space decisions that are made for the Delaware River and Crosswicks Creek watersheds will favor sustainable ecosystems in the study area.

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### Appendix 1.

Vascular plants of the Hamilton–Trenton–Bordentown Marsh. Taxa have been arranged in the following categories: vascular cryptogams (lycophods, horsetails, and ferns), gymnosperms, dicots, and monocots. Cultivated ephemerals are listed separately at the end. Alphabetical within each category are families and lower taxa. Each entry contains scientific name and authority. (Sources were Rhoads and Klein (1993) and, if a species is not recorded for Pennsylvania, then we used Gleason and Cronquist (1991). For *Kyllinga* we used Bryson, et al. (1997)). Additional notations may include: (1988) - species listed by Leck et al (1988); RM - reference marsh; CW - constructed wetland; sb - emerging from seed bank or spore bank soil samples; RM f are field species from Leck and Simpson 1987a, b; CW f are constructed wetland species recorded at the site (note that RM f and CW f designations do not preclude occurrences in other areas); and \* indicates non-native species. Species that we have not seen ourselves are credited to their source, e.g., J. Arsenault, R. Blicharz, D. Snyder, or A. E. Schuyler (including specimens at the Academy of Natural Sciences of Philadelphia herbarium). We have also indicated, where appropriate, others who provided identifications. Species also listed by Bonaparte (1824) are indicated as [Bonaparte], by Abbott (1887), as [Abbott] and any additional species found in Abbott 1886, 1892, 1897, and 1898 as [Abbott +], and by Shoemaker 1964 or 1965, as [Shoemaker]. (Other species found in Bonaparte (1824), Abbott (1886, 1887) or Shoemaker (1964, 1965) appear in Appendix 2). Other comments considered to be of interest are also provided. For a list of New Jersey rare or endangered species see Table 3.

#### Ferns and Fern Allies

##### LYCOPODIOPHYTA

###### Isoetaceae

*Isoetes riparia* Engelm. ex A. Braun. CW f. Several plants were observed once during fall 1994 in a shallow depression near the east navigation beacon.

###### Lycopodiaceae

*Huperzia lucidula* (Michx.) Trevisan. One small plant located near Spring Lake trails bridge. Did not persist; area flooded due to beaver activity.

*Lycopodium obscurum* L. Extensive patches near Sturgeon Pond and at N. Community Park.

###### Selaginellaceae

*Selaginella apoda* (L.) Fern. Observed once on a path in woods near Sturgeon Pond east.

##### EQUISETOPHYTA

###### Equisetaceae

*Equisetum arvense* L. (1988). CW f. [Abbott] [Shoemaker].

*Equisetum fluviatile* L. (1988). CW f. Infrequent.

*Equisetum hyemale* L. var. *affine* x *laevigatum*. Location on Duck Is. destroyed by highway construction.

*Equisetum* sp. (1988) RM sb.

##### PTERIDOPHYTA

###### Aspleniaceae

*Asplenium platyneuron* (L.) BSP. (1988).

###### Blechnaceae

*Woodwardia areolata* (L.) T.Moore. (1988). RM sb.

*Woodwardia virginica* (L.) Smith. RM sb only. Young plant from soil sample identified by J. Montgomery.

###### Dennstaedtiaceae

*Dennstaedtia punctilobula* (Michx.) T.Moore. (1988). RM sb. [Shoemaker].

*Pteridium aquilinum* (L.) Kuhn. Bordentown Bluffs along Crosswicks Creek. [Abbott+].

###### Dryopteridaceae

*Athyrium filix-femina* (L.) Roth. (1988). RM sb. [Shoemaker].

*Cystopteris tenuis* (Michx.) Desv. Between grouted rocks of old bridge abutment near Yardville.

*Dryopteris carthusiana* (Villars) H.P. Fuchs. (1988).

*Dryopteris intermedia* (Muhl. ex Willd.) A.Gray

*Dryopteris marginalis* (L.) A.Gray

*Dryopteris* sp. (1988). RM sb.

*Matteuccia struthiopteris* (L.) Todaro. (1988). Infrequent.

*Onoclea sensibilis* L. (1988). RM sb, CW sb, RM f, CW f. Most common fern in soil samples (Leck and Simpson 1987b). [Shoemaker].

*Polystichum acrostichoides* (Michx.) Schott. (1988). [Abbott+].

*Woodsia obtusa* (Spreng.) Torr. Growing between rocks of abandoned bridge abutment on Delaware River north of PSE&G.

#### Ophioglossaceae

*Botrychium dissectum* Spreng. (1988). CW f. D & R Canal tow path on Duck Is. and forested island near RM.

*Botrychium virginianum* (L.) Swartz. (1988). Spring Lake trails.

#### Osmundaceae

*Osmunda cinnamomea* L. (1988). [Abbott+] [Shoemaker].

*Osmunda claytoniana* L. (1988). Infrequent. [Shoemaker].

*Osmunda regalis* L. (1988). Infrequent; several populations at Yardville - Delaware & Raritan Canal State Park.

#### Thelypteridaceae

*Thelypteris noveboracensis* (L.) Nieuwl. (1988). CW f. [Shoemaker].

*Thelypteris palustris* Schott (1988). RM sb.

#### Seed Plants

PINOPHYTA (Gymnosperms)

#### Cupressaceae

*Chamaecyparis thyoides* (L.) BSP. Several trees at edge of marsh near Bordentown Water Authority building, east of bridge at Rt. 206 - Crosswicks Creek. [Abbott refers to 'cedars along riverbanks']. Stumps visible at low tide along Watson Creek may be this species.

*Juniperus virginiana* L. Local, near Spring Lake. [Bonaparte] [Abbott+].

#### Pinaceae

\**Picea abies* (L.) Karst. South tip Duck Island.

*Pinus rigida* P.Mill. (1988). Infrequent, Bordentown Bluffs.

*Pinus strobus* L. CW f. Infrequent. [Shoemaker].

*Tsuga canadensis* (L.) Carr. Infrequent, Bordentown Bluffs; many trees killed by wooly adelgid infestation. A notable tree was 45 cm DBH (2004).

#### Taxaceae

\**Taxus* spp. (1988). Planted at abandoned homesites (near Spring Lake and south tip of Duck Is. near Delaware & Raritan Canal).

MAGNOLIOPHYTA (Flowering Plants)

MAGNOLIOPSIDA (Dicotyleydoms)

#### Acanthaceae

*Justicia americana* (L.) Vahl. (1988). CW f. Several populations along Delaware River, vicinity of CW, Trenton boat launch, and I 295 scenic overlook; upper intertidal on cobble.

#### Aceraceae

*Acer negundo* L. (1988). CW sb, CW f. [Abbott] [Shoemaker].

\**Acer palmatum* Thunb. Escaped, woods near Yardville storm drain.

\**Acer platanoides* L. (1988).

\**Acer pseudoplatanus* L. (1988). [Shoemaker].

*Acer rubrum* L. (1988). RM f, CW f. [Abbott] [Shoemaker].

*Acer saccharinum* L. (1988). CW sb, RM f, CW f.

*Acer saccharum* Marshall. Several sizable trees along road from Spring Lake to Watson Woods, likely planted.

#### Amaranthaceae

*Amaranthus cannabinus* (L.) Sauer (1988). RM sb, CW sb, RM f, CW f.

\**Amaranthus retroflexus* L. CW f.

\**Froelichia gracilis* (Hook.) Moq. (1988). CW f.

#### Anacardiaceae

*Rhus copallina* L. (1988).

*Rhus glabra* L. Infrequent. (1988). Noted in 1987 along road near brick factory. [Shoemaker].

*Rhus typhina* L. (1988). CW f [Shoemaker].

*Toxicodendron radicans* (L.) Kuntze. (1988). CW sb, RM f, CW f. [Abbott] [Shoemaker].

#### Apiaceae

*Cicuta bulbifera* L. (1988). CW sb, CW f.

*Cicuta maculata* L. (1988). RM sb, CW sb, RM f, CW f.

*Cryptotaenia canadensis* (L.) DC.

\**Daucus carota* L. (1988). CW f.

*Heracleum lanatum* Michx. (1988). RM f. Roadside at Watson Woods, along railroad, and Lambertson Road.

\**Hydrocotyle sibthorpioides* Lam. Bordentown beach, Trenton boat launch.

*Osmorhiza claytonii* (Michx.) C.B. Clarke

*Osmorhiza longistylis* (Torr.) DC. (1988).

\**Pastinaca sativa* L.

*Ptilimnium capillaceum* (Michx.) Raf. (1988, Arsenault).

*Sanicula odorata* (Raf.) Pryer & Phillippe

*Sium sauve* Walt. (1988). RM sb, CW sb, RM f, CW f.

#### Apocynaceae

*Apocynum androsaemifolium* L. (1988).

*Apocynum cannabinum* L. (1988). CW sb, CW f.

\**Vinca minor* L. At abandoned homesites. [Shoemaker].

#### Aquifoliaceae

*Ilex opaca* Ait. (1988). Infrequent.

*Ilex verticillata* (L.) A.Gray. (1988). CW sb. [Abbott] [Shoemaker].

#### Araliaceae

*Aralia nudicaulis* L. Bordentown Bluffs, Watson Woods.

\**Hedera helix* L. Extensive patches at Bordentown Bluffs and bluffs near Rowan St. storm drain.

#### Aristolochiaceae

*Asarum canadense* L. (1988). CM f. Extensive patch on floodplain east side of Duck Creek.

#### Asclepiadaceae

*Asclepias incarnata* L. (1988). CW f. [Shoemaker]. Many plants along edge of Spring Lake in 2004.

*Asclepias syriaca* L. (1988). CW f. [Shoemaker].

#### Asteraceae

\**Achillea millefolium* L. (1988). CW f. [Abbott+].

*Ambrosia artemisiifolia* L. (1988). CW sb, CW f.

*Ambrosia trifida* L. (1988). RM sb, RM f, CW f. Large populations can occur on tidal channel levees.

*Antennaria plantaginifolia* (L.) Richardson. Site on Duck Is. destroyed during excavation for con-

- structed wetland; one site on Bordentown Bluffs near Stanton Ave. in 2004.
- \**Anthemis arvensis* L.  
 \**Anthemis cotula* L. (1988).  
 \**Anthemis tinctoria* L. CW f.  
 \**Arctium minus* (Hill.) Bernh.  
 \**Artemisia annua* L. CW f.  
 \**Artemisia vulgaris* L. (1988). CW sb, CW f.  
*Aster cordifolius* L. CW f.  
*Aster divaricatus* L. *sensu lato* (1988).  
*Aster dumosus* L. *sensu lato*. CW f.  
*Aster ericoides* L. CW sb, CW f.  
*Aster fragilis* Willd. var. *fragilis* (including *A. racemosus* and *A. vimineus*). (1988). CW sb, CW f.  
*Aster lanceolatus* Willd. ssp. *simplex* (Willd.) A.G.Jones (1988). CW f.  
*Aster longifolius* Lam. *sensu lato* (*A. praealtus* Poir. identified by J. Meyer).  
*Aster pilosus* Willd. (1988). RM sb, CW sb, RM f, CW f.  
*Aster puniceus* L. (1988). CW sb, CW f.  
*Baccharis halimifolia* L. (1988). RM sb, CW f.  
*Bidens bidentoides* (Nutt.) Britt.. (1988). CW sb, CW f. May be locally numerous, upper intertidal along Delaware River where there is disturbance; Trenton boat launch on Lamberton Road and elsewhere.  
*Bidens bipinnata* L. CW f.  
*Bidens cernua* L. CW f.  
*Bidens comosa* (A.Gray) Wieg. (1988, Schuyler). CW sb.  
*Bidens connata* MuhL. (1988). CW sb, CW f. Locally abundant, e.g., 2003 marsh near Sturgeon Pond east.  
*Bidens coronata* (L.) Britt. (1988) CW f.  
*Bidens discoidea* (Torr. & Gray) Britt.  
*Bidens frondosa* L. (1988). RM sb, CW sb, RM f, CW f.  
*Bidens laevis* (L.) BSP. (1988). RM sb, CW sb, RM f, CW f.  
 \**Bidens polylepis* S.F.Blake (1988). CW sb, CW f.  
*Bidens tripartita* L. CW sb.  
*Cacalia atriplicifolia* L.. Two plants found in 1992 and for several years, but not recently (2001, 2002), Crosswicks Creek floodplain southwest (upstream) of railroad bridge at Yardville.  
 \**Carduus nutans* L. Roadside on Duck Is.  
 \**Centaurea maculosa* Lam. (1988). CW f.  
 \**Chrysanthemum leucanthemum* L. (1988).  
 \**Cichorium intybus* L. CW f.  
 \**Cirsium arvense* (L.) Scop. (1988). CW f.  
 \**Cirsium vulgare* (Savi) Tenore. (1988). CW sb; CW f. [Abbott].  
*Conyza canadensis* (L.) Cronq. (1988). RM sb, CW sb; CW f.  
 \**Coreopsis lanceolata* L. Roadside near PSE&G on Lamberton Road.  
 \**Crepis tectorum* L.  
*Eclipta prostata* (L.) L. CW sb, CW f.  
*Erechtites hieraciifolia* (L.) Raf. ex DC. (1988). RM sb, CW sb, RM f, CW f.  
*Erigeron annuus* (L.) Pers. (1988). RM sb, CW sb, CW f.  
*Erigeron philadelphicus* L. CW f.  
*Erigeron strigosus* Muhl. ex Willd.  
*Eupatorium album* L. var. *subvenosum* A.Gray. CW f. [Shoemaker].  
*Eupatorium altissimum* L.. CW f. CW along road to beacon (1996) and near Sturgeon Pond west (1992, 1993) where *Sorghastrum nutans* was present.  
*Eupatorium aromaticum* L. (2 Aug. 1992).  
*Eupatorium dubium* Willd. ex Poir. (1988). RM sb, RM f, CW f.  
*Eupatorium fistulosum* Barratt. CW f.  
*Eupatorium hyssopifolium* L. (1988). CW f.  
*Eupatorium leucolepis* (DC.) Torr. & A.Gray. Near Sturgeon Pond.  
*Eupatorium maculatum* L. CW f.  
*Eupatorium perfoliatum* L. (1988). CW sb, CW f. [Abbott].  
*Eupatorium purpureum* L. (1988). RM f, CW f. [Shoemaker].  
*Eupatorium rotundifolium* L.  
*Eupatorium rugosum* Houtt. (1988). CW sb, CW f.  
*Eupatorium serotinum* Michx. CW sb, CW f. Dominant on Elatine Is. upland several years including 2003. Also, during 1995-1997 on CW north marsh near channel.  
*Euthamia graminifolia* (L.) Nutt. (1988). RM sb, CW sb, CW f.  
 \**Galinsoga quadriradiata* Ruiz & Pavon. CW f.  
*Gnaphalium obtusifolium* L. (1988). RM sb, RM f, CW f.  
*Gnaphalium uliginosum* L. CW sb, CW f.  
*Helenium autumnale* L. (1988). CW sb, CW f. [Abbott].  
*Helianthus annuus* L. (1988, Blicharz).  
*Helianthus decapetalus* L. (1988). CW f.  
*Helianthus tuberosus* L. (1998). CW f.  
*Heterotheca subaxillaris* (Lam.) Britt. & Rusby. CW f.  
 \**Hieracium caespitosum* Dumort. (1988). CW f.  
*Hieracium gronovii* L.  
 \**Hieracium piloselloides* Vill.  
*Hieracium venosum* L. Hillside near railroad, Yardville.  
 \**Hypochoeris radicata* L.  
*Krigia biflora* (Walt.) S.F.Blake. West trail, Spring Lake.  
*Krigia virginica* (L.) Willd. (1988). CW f. [Abbott].  
*Lactuca biennis* (Moench) Fern. Beneath railroad bridge, Yardville; Watson Woods.  
*Lactuca canadensis* L. (1988). RM sb, RM f, CW f.  
 \**Lactuca serriola* L. CW f.  
*Lactuca* sp. CW sb.  
 \**Matricaria perforata* Merat. CW f.  
*Mikania scandens* (L.) Willd. (1988). RM sb, CW sb, RM f, CW f. Common; dominant at CW. [Abbott].  
*Prenanthes trifoliolata* (Cass.) Fern. Wooded hillside D & R Canal State Park near railroad (Yardville).  
*Rudbeckia hirta* L. (1988). CW f.  
*Rudbeckia laciniata* L. (1988). CW f. [Abbott].  
*Senecio aureus* L. (1988). [Abbott].  
 \**Senecio vulgaris* L. CW f.  
*Solidago caesia* L. (1988). Wooded hillsides near Yardville and near Rowan St. drain.  
*Solidago canadensis* L. (1988). RM sb, CW sb, RM f, CW f.  
*Solidago canadensis* var. *scabra* L. Torr. & A.Gray. CW f.  
*Solidago gigantea* Ait. CW f.  
*Solidago juncea* Ait. (1988). CW f.  
*Solidago rugosa* Ait. (1988). CW sb, CW f.  
*Solidago sempervirens* L. (1988). CW f.  
 \**Sonchus asper* (L.) Hill. CW f.  
 \**Taraxacum laevigatum* (Willd.) DC.

\**Taraxacum officinale* Weber (1988). CW sb, CW f. [= *Taraxacum dens-leonis*, Abbott+].

\**Tragopogon dubius* Scop. Open area near beach at Stanton Ave.

*Verbesina alternifolia* (L.) Britt. CW sb, CW f.

*Vernonia noveboracensis* (L.) Michx. CW sb, CW f. Common along Delaware River upper intertidal shore and frequent on high marsh of CW. [Abbott+].

*Xanthium strumarium* L. (1988). CW f.

#### Balsaminaceae

*Impatiens capensis* Meerb. (1988). RM sb, CW sb, RM f, CW f. [Abbott].

*Impatiens pallida* Nutt. Duck Is. along Lamberton Road, north of PSE&G.

#### Berberidaceae

\**Berberis thunbergii* DC. (1988).

*Podophyllum peltatum* L. (1988). [Bonaparte] [Abbott].

#### Betulaceae

\**Alnus glutinosa* (L.) Gaertn. CW sb, CW f.

*Alnus incana* (L.) Moench. [Shoemaker].

*Alnus serrulata* (Dryand. ex Ait.) Willd. (1988). RM sb, RM f [Abbott].

*Betula lenta* L. Bordentown Bluffs.

*Betula nigra* L. (1988). RM sb, CW sb, RM f, CW f. [Abbott].

*Betula populifolia* Marshall. (1988). RM sb, RM f.

*Carpinus caroliniana* Walt. (1988).

*Corylus americana* Walt. [Abbott].

#### Bignoniaceae

*Campsis radicans* (L.) Seem. ex Bureau. [Abbott].

*Catalpa bignonioides* Walt. (1988). CW f. [Abbott].

\**Paulownia tomentosa* (Thunb.) Sieb. & Zucc. ex Steud. (1988). RM sb, CW sb, RM f, CW f.

#### Boraginaceae

\**Echium vulgare* L.

*Hackelia virginiana* (L.) I.M. Johnston

*Mertensia virginica* (L.) Pers. ex Link. Crosswicks Creek floodplain near Yardville.

\**Myosotis arvensis* (L.) Hill. CW f.

*Myosotis laxa* Lehm. (1988). RM sb, CW sb, RM f, CW f.

#### Brassicaceae

\**Alliaria petiolata* (Bieb.) Cavara & Grande. (1988). CW f.

\**Arabidopsis thaliana* (L.) Heynh. CW f.

*Arabis laevigata* (Muhl. ex Willd.) Poir. (1988). CW f.

*Barbarea verna* (P.Mill.) Aschers.

\**Barbarea vulgaris* R.Br. CW f.

\**Brassica nigra* (L.) W.D.J.Koch. CW f.

\**Camelina microcarpa* Andrz. ex DC. Disturbed upland at little mitigation site.

\**Capsella bursa-pastoris* (L.) Medic. (1988). [Bonaparte].

*Cardamine bulbosa* (Schreb. ex Muhl.) BSP. (1988). RM sb, RM f.

*Cardamine concatenata* (Michx.) O.E.Schulz. [Shoemaker].

*Cardamine hirsuta* L. CW f.

*Cardamine pensylvanica* Muhl. ex Willd. (1988). RM sb, CW sb, CW f.

\**Diplotaxis tenuifolia* (L.) DC. CW f. One plant that

persisted for several years until Tide Pool Is. became overgrown.

\**Eriophila verna* (L.) Chev. CW f. [Abbott+].

\**Hesperis matronalis* L. CW f.

*Lepidium virginicum* L. CW f.

*Lepidulum* sp. (1988).

\**Nasturtium officinale* R.Br. (1988). RM sb, RM f.

*Rorippa palustris* (L.) Bess. CW sb, CW f.

\**Sisymbrium altissimum* L. Disturbed upland at little mitigation site.

\**Sisymbrium officinale* (L.) Scop. Disturbed upland at little mitigation site.

\**Thlaspi arvense* L. CW f.

#### Buxaceae

\**Pachysandra terminalis* Siebold & Zucc.

#### Cabombaceae

*Cabomba caroliniana* A.Gray. (1988). [Shoemaker].

#### Caesalpiniaceae

*Chamaecrista fasciculata* (Michx.) Greene (1988).

*Chamaecrista nictitans* (L.) Moench. (1988). CW f.

*Gleditsia triacanthos* L. CW f. [Bonaparte].

*Senna hebecarpa* (Fern.) Irwin & Barneby. CW f; one plant several years on D.O.T. Is. and also Elatine Is. in 2004.

#### Callitrichaceae

*Callitriche heterophylla* Pursh *emend.* Darby. (1988). RM sb, RM f, CW f.

\**Callitriche stagnalis* Scop. CW f.

#### Campanulaceae

*Campanula aparinoides* Pursh. Infrequent; alder swamp at Watson Woods and Yardville-D & R Canal State Park.

*Lobelia cardinalis* L. (1988). CW sb, CW f. Regular along Duck Creek. [Abbott].

*Lobelia inflata* L. (1988). CW f.

*Lobelia siphilitica* L. (1988). CW sb, CW f. Infrequent.

*Triodanis perfoliata* (L.) Nieuwl. (1988). CW f.

#### Cannabaceae

\**Humulus japonicus* Sieb. & Zucc. (1988). CW f.

#### Caprifoliaceae

\**Lonicera japonica* Thunb. (1988). RM f, CW f.

\**Lonicera morrowii* A.Gray. (1988). CW f.

*Lonicera sempervirens* L. Two locations at Bordentown Bluffs (along trail and ravine west of Stanton Ave. beach). [Abbott+].

\**Lonicera xylosteum* L. (1988).

*Sambucus canadensis* L. (1988). RM f, CW f. [Abbott] [Shoemaker].

*Viburnum acerifolium* L. Bordentown Bluffs and N, Community Park. [Shoemaker].

*Viburnum dentatum* L. (1988). RM sb, RM f, CW f. [Abbott] [Shoemaker].

*Viburnum prunifolium* L. (1988). RM sb, RM f, CW f. [Abbott].

#### Caryophyllaceae

\**Arenaria serpyllifolia* L. CW f.

\**Cerastium semidecandrum* L. CW f.

\**Dianthus armeria* L. (1988). CW f.

*Paronychia fastigiata* (Raf.) Fern. CW f.

\**Sagina japonica* (Swartz) Ohwi. CW f.

*Sagina procumbens* L. CW f.

*Sagina* sp. CW sb.

\**Saponaria officinalis* L. (1988). CW f. [Abbott+].

\**Scleranthus annuus* L. CW f.

\**Silene alba* (Mill.) Krause

*Silene antirrhina* L. [Bonaparte].

*Silene caroliniana* Walt. Small population near railroad northeast of railroad bridge at Yardville.

\**Silene noctiflora* L.

*Silene stellata* (L.) Ait.f. CW f. Hillsides near Yardville, Spring Lake, and CW on Tide Pool Is.

\**Spergula arvensis* L. CW f.

*Stellaria longifolia* Muhl. ex Willd. (1988).

\**Stellaria media* (L.) Vill. CW f. [Abbott+].

#### Celastraceae

\**Celastrus orbiculatus* Thunb. (1988). CW f.

\**Euonymus alatus* (Thunb.) Sieb. (1988).

#### Ceratophyllaceae

*Ceratophyllum demersum* L. (1988). CW f.

#### Chenopodiaceae

*Atriplex prostrata* Boudier ex DC. CW sb, CW f.

\**Chenopodium album* L. (1988). CW sb, CW f.

\**Chenopodium ambrosioides* L. (1988). CW sb, CW f.

\**Chenopodium pumilio* R.Br.

\**Cycloloma atriplicifolium* (Spreng.) Coult. (1988).

#### Cistaceae

*Lechea villosa* Ell. (1988).

#### Clethraceae

*Clethra alnifolia* L. (1988). [Abbott].

#### Clusiaceae

*Hypericum gentianoides* (L.) BSP

*Hypericum mutilum* L. (1988). CW sb, CW f.

\**Hypericum perforatum* L. (1988). CW f.

*Hypericum punctatum* Lam. CW sb, CW f

*Triadenum virginicum* (L.) Raf. (1988). RM sb, CW sb.

#### Convolvulaceae

*Calystegia sepium* (L.) R.Br. *sensu lato*. (1988). CW f. [Abbott].

\**Convolvulus arvensis* L. CW f.

\**Ipomoea hederacea* Jacq.

*Ipomoea pandurata* (L.) G.F.W. Mey.

#### Cornaceae

*Cornus alternifolia* L.f. Northern Community Park.

*Cornus anomum* P.Mill. (1988). RM sb, RM f, CW f.

*Cornus florida* L. (1988). CW f. [Bonaparte] [Abbott].

*Cornus racemosa* Lam.

*Cornus sericea* L.

*Cornus* sp. CW sb.

#### Crassulaceae

\**Sedum acre* L.

\**Sedum sarmentosum* Bunge. CW f.

\**Sedum purpureum* (L.) J.A. Schultes (or *S. telephium* L.)

#### Cucurbitaceae

*Sicyos angulatus* L. CW f.

#### Cuscutaceae

*Cuscuta compacta* Juss. ex Choisy. Sturgeon Pond, identified by D. Snyder (Aug. 1993).

*Cuscuta gronovii* Willd. ex Schultz (1988). RM sb, CW sb, RM f, CW f. [Abbott].

*Cuscuta polygonorum* Engelm. CW f. Infrequent; no information about persistence.

#### Droseraceae

*Drosera rotundifolia* L. (1988). RM sb only.

#### Ebenaceae

*Diospyros virginiana* L. (1988). CW f. Crosswicks Creek floodplain, N. Community Park. [Abbott].

#### Elaeagnaceae

\**Elaeagnus umbellata* Thunb. CW f.

#### Elatinaceae

*Elatine americana* (Pursh) Arn. CW f, in 'tidal' pools; observed for several years but not in 2004.

#### Ericaceae

*Epigaea repens* L. Infrequent, Bordentown Bluffs and along trail at N. Community Park. [Abbott+].

*Kalmia latifolia* L. Forming thickets along Bordentown Bluffs, also N. Community Park. [Abbott].

*Rhododendron* (?) *canescens* (Michx.) Sweet. South end of Duck Is. near Bordentown.

*Rhododendron maximum* L. Forming thickets along Bordentown Bluffs. [Bonaparte].

*Rhododendron periclymenoides* (Michx.) Shinn. Occasional plants along Crosswicks Creek, common at N. Community Park. [Abbott+].

*Vaccinium corymbosum* L. (1988).

*Vaccinium pallidum* Ait. Bordentown Bluffs area.

*Vaccinium stamineum* L. Bordentown Bluffs. [Abbott+].

#### Euphorbiaceae

*Acalypha rhomboidea* Raf. CW sb, CW f.

*Acalypha virginica* L. (1988). CW sb, CW f.

*Chamaesyce maculata* (L.) Small. CW sb, CW f.

*Chamaesyce nutans* (Lag.) Small

*Euphorbia corollata* L. (1988). Open upland along Spring Lake trails; area now has tree canopy.

*Poinsettia dentata* (Michx.) Klotzsch & Garcke. Along railroad at Yardville.

#### Fabaceae

*Amorpha fruticosa* L. (1988). CW sb, CW f. Common colonizer along wetland upland edges of CW.

*Amphicarpea bracteata* (L.) Fern. (1988). CW f. [Abbott].

*Apios americana* Medic. (1988). CW f. Locally common. [Abbott].

\**Coronilla varia* L. (1988). CW f.

*Crotalaria sagittalis* L.

*Desmodium canadense* (L.) DC.

*Desmodium canescens* (L.) DC. (1988, Arsenault).

*Desmodium glabellum* (Michx.) DC.

*Desmodium paniculatum* (L.) DC. Identified by W. Standaert.

\**Kummerowia stipulacea* (Maxim.) Schindler

\**Kummerowia striata* (Thunb.) Shindl. CW f.

\**Lathyrus latifolius* L.

*Lespedeza capitata* Michx. (1988). CW f.

\**Lespedeza cuneata* (Dum.-Cours.) G.Don. CW f.

*Lespedeza intermedia* (S.Wats.) Britt. (1988). CW f.

*Lespedeza violacea* (L.) Pers.

\**Lotus corniculatus* L. CW f.

\**Medicago lupulina* L.

\**Medicago sativa* L.

\**Melilotus alba* Medic. (1988). CW f.

\**Melilotus officinalis* (L.) Pallas. (1988). CW f.

*Robinia pseudoacacia* L. (1988). CW sb, CW f. Common colonizer edges of CW and islands. [Bonaparte] [Abbott].

*Strophostyles helvola* (L.) Ell. CW sb, CW f.

\**Trifolium arvense* L. (1988). CW f.

\**Trifolium aureum* Pollich (1988). CW f.

\**Trifolium campestre* Schreb.

\**Trifolium dubium* Sibth. CW f.

\**Trifolium hybridum* L. CW f.

\**Trifolium pratense* L. (1988). CW f. [Abbott].

\**Trifolium repens* L. (1988). CW sb, CW f. [Bonaparte].

\**Vicia sativa* L. CW f.

\**Vicia tetrasperma* (L.) Schreb.

\**Wisteria floribunda* (Willd.) DC. (1988).

### Fagaceae

*Castanea dentata* (Marshall) Borkh. Several plants, Bordentown Bluffs and N. Community Park. [Abbott].

*Fagus grandifolia* Ehrh. (1988). CW f. [Abbott] [Shoemaker].

*Quercus alba* L. [Bonaparte] [Abbott] [Shoemaker].

*Quercus bicolor* Willd. [Bonaparte] [Abbott].

*Quercus marilandica* Muenchh. Identified by J. Meyer.

*Quercus michauxii* Nutt.

*Quercus montana* Willd. [Bonaparte].

*Quercus muhlenbergii* Engelm.

*Quercus palustris* Muenchh. (1988). RM f, CW f. [Bonaparte] [Abbott+] [Shoemaker].

*Quercus phellos* L. (1988). Sunny Pond near Spring Lake spillway; also one tree along road from Duck Island to Spring Lake in 1986. [Abbott+] noted a plantation of this species.

*Quercus rubra* L. (1988). RM f. [Bonaparte] [Shoemaker].

*Quercus stellata* Wang. [Abbott+].

*Quercus velutina* Lam.

### Fumariaceae

*Corydalis flavula* (Raf.) DC. (1988). CW f. [Abbott+].

*Dicentra cucullaria* (L.) Bernh. (1988). Abbott (1886) called this 'Eardrops', perhaps more politically correct at the time than 'Dutchman's Breeches'. [Abbott+] [Shoemaker].

### Gentianaceae

*Bartonia paniculata* (Michx.) Muhl. Near Sturgeon Pond east.

*Bartonia virginica* (L.) BSP. N. Community Park.

### Geraniaceae

*Erodium cicutarium* (L.) L'Her. ex Soland.

*Geranium carolinianum* L. CW f. [Bonaparte].

*Geranium maculatum* L. Bordentown Bluffs and Crosswicks Creek floodplain at Yardville. [Abbott+].

### Haloragaceae

*Myriophyllum heterophyllum* Michx. (1988, Schuyler).

\**Myriophyllum spicatum* L. (1988). CW sb, CW f. [Abbott].

*Proserpinaca palustris* L. Sturgeon Pond and contiguous marsh, near landfill.

### Hamamelidaceae

*Hamamelis virginiana* L. [Abbott+].

*Liquidambar styraciflua* L. (1988). RM sb, RM f, CW f. [Bonaparte] [Abbott].

### Hippocastanaceae

*Aesculus flava* Ait. Wooded hillside at Point Breeze overlooking Crosswicks Creek; regeneration is apparent.

*Aesculus hippocastanum* L. Duck Is., infrequent.

### Hydrangeaceae

*Hydrangea arborescens* L. Steep wooded hillside near Blacks Creek, west of Bordentown.

\**Philadelphus coronarius* L. (1988). Bordentown Bluffs.

### Hydrophyllaceae

*Hydrophyllum virginianum* L. Floodplain along Watson Creek.

### Juglandaceae

*Carya cordiformis* (Wang.) K.Koch (1988).

*Carya glabra* (P.Mill.) Sweet [Abbott].

*Carya ovata* (P.Mill.) K.Koch. RM f. [Abbott].

*Carya tomentosa* (Lam. ex Poir.) Nutt. [Bonaparte].

*Juglans nigra* L. CW f. [Bonaparte] [Abbott].

### Lamiaceae

*Agastache nepetoides* (L.) Kuntze. Old road near sludge lagoon at Hamilton water treatment plant. [= *Lophanthus nepethoides* Benth. Abbott+].

*Agastache scrophulariifolia* (Willd.) Kuntze (1988) Observed along east end of old road by sludge lagoon at Hamilton Water Treatment Plant; hillside near Sturgeon Pond east.

*Collinsonia canadensis* L. Bordentown Bluffs.

*Dracocephalum parviflorum* Nutt. CW f.

\**Elsholtzia ciliata* (Thunb.) Hylander. CW f; noted near northernmost inlet in 1996; frequent along edges of several islands in 2003.

\**Glechoma hederacea* L. (1988). CW f.

*Hedeoma pulegioides* (L.) Pers. CW sb.

\**Lamium amplexicaule* L. (1988, Blicharz). CW f.

\**Lamium purpureum* L.

\**Leonurus cardiaca* L. (1988). CW f. Roadsides at Watson Woods.

*Lycopus americanus* Muhl. ex Bart. (1988). CW sb, CW f.

\**Lycopus europaeus* L. CW sb, CW f.

*Lycopus rubellus* Moench. CW sb, CW f.

*Lycopus virginicus* L. (1988). RM sb, CW sb, RM f, CW f.

*Mentha arvensis* L. CW sb, CW f. Occasional in tidal areas.

*Monarda fistulosa* L.

\**Nepeta cataria* L.

\**Perilla frutescens* (L.) Britt. CW f; at north inlet in 1996 and on several islands in 2003.

\**Prunella vulgaris* L. (1988). CW sb, CW f.

*Pycnanthemum tenuifolium* Schrad. (1988).

*Pycnanthemum verticillatum* (Michx.) Pers.

*Pycnanthemum virginianum* (L.) Durand & Jackson ex B.L.Robins & Fern. (1988, Blicharz).

*Salvia lyrata* L.

*Scutellaria galericulata* L. (1988). CW sb, CW f.

*Scutellaria integrifolia* L. (1988). CW f.

*Scutellaria lateriflora* L. (1988). RM sb, CW sb, RM f, CW f.

*Stachys palustris* L. (1988, Schuyler). CW f.

*Stachys tenuifolia* Willd. var *hispida* (1988). ?S3. RM f, CW f.

*Teucrium canadense* L. (1988). CW f.

*Trichostema dichotomum* L. (1988). CW f.

### Lauraceae

*Lindera benzoin* (L.) Blume (1988). CW f. [Abbott+].

*Sassafras albidum* (Nutt.) Nees. (1988). RM f, CW f. [Bonaparte] [Abbott+].

#### Lentibulariaceae

*Utricularia gibba* L. Sturgeon Pond and Spring Lake.

*Utricularia intermedia* Hayne. (1988, Schuyler).

*Utricularia macrorhiza* Leconte (*U. vulgaris* L.). (1988, Schuyler).

*Utricularia radiata* Small. At west end of Spring Lake, flowering late April 2002.

#### Limnanthaceae

*Floerkea proserpinacoides* Willd. Common, Crosswicks Creek floodplain near Yardville.

#### Loganiaceae

\**Buddleja davidii* Franch. Common along railroad on Duck Is.

#### Lythraceae

*Decodon verticillatus* (L.) Ell. Beaver pond west of the Spring Lake spillway, noted in 2002.

*Lythrum alatum* Pursh (1988). RM f. Ranked 11<sup>th</sup> (of 22) in importance in open marsh vegetation by Whigham and Simpson (1975), but has not been observed by authors.

\**Lythrum salicaria* L. (1988). RM sb, CW sb, RM f, CW f. Not recorded by Whigham and Simpson (1975) in open marsh or shrub forest plots. Generally infrequent except in CW.

#### Magnoliaceae

*Liriodendron tulipifera* L. (1988). RM sb, CW sb, RM f, CW f. [Bonaparte] [Abbott].

*Magnolia tripetala* L. Along Bordentown Bluffs and at Divine Word Missionaries easement in woods near Park Street.

*Magnolia virginiana* L. One sizable tree at Abbott's swamp, and a few small trees at N. Community Park. [Bonaparte] [Abbott].

#### Malvaceae

\**Abutilon theophrastii* Medic. CW f.

*Hibiscus moscheutos* L. (1988). RM sb, CW sb, RM f, CW f. [Abbott+] [Shoemaker].

\**Hibiscus trionum* L. CW f.

\**Malva neglecta* Wallr. CW f.

#### Melastomataceae

*Rhexia virginica* L. (1988). Infrequent.

#### Menispermaceae

*Menispermum canadense* L. CW f.

#### Mimosaceae

\**Albizia julibrissin* Durazz. CW f.

#### Molluginaceae

\**Mollugo verticillata* L. (1988). CW sb, CW f.

#### Monotropaceae

*Monotropa uniflora* L. (1988). Infrequent Sturgeon Pond area; Forest Is. near RM, Watson Woods.

#### Moraceae

\**Broussonetia papyrifera* (L.) Vent. (1988). Abbott's homesite area.

\**Maclura pomifera* (Raf. Ex Sarg.) Schneid. One small plant near Trenton boat launch.

\**Morus alba* L. (1988). CW f.

*Morus rubra* L. CW f. [Bonaparte].

#### Myricaceae

*Comptonia peregrina* (L.) Coult.

#### Nelumbonaceae

*Nelumbo lutea* (Willd.) Pers. Schuyler, herbarium only. [Abbott]. A photograph (Abbott 1892) shows this growing in a garden tub.

#### Nyctaginaceae

*Mirabilis nyctaginea* (Michx.) MacM. Duck Is., along Lambertson Road.

#### Nymphaeaceae

*Nuphar lutea* (L.) Sibth. & Smith *sensu lato*. (1988). RM sb, CW sb, RM f, CW f. [Abbott] [Shoemaker].

*Nymphaea odorata* Ait. (1988). Once common (Clyde Quin, pers. comm.); only observed in Sturgeon Pond west. Plantings in CW (Tide Pool Is.) apparently extirpated by 2004. [Abbott+] [Shoemaker].

#### Nyssaceae

*Nyssa sylvatica* Marshall. (1988). CW sb, RM f, CW f. [Abbott] [Shoemaker].

#### Oleaceae

*Fraxinus americana* L. (1988). RM sb, RM f, CW f. [Abbott+].

*Fraxinus pennsylvanica* Marshall (1988). CW sb, RM f, CW f.

\**Ligustrum obtusifolium* Sieb. & Zucc.

\**Ligustrum vulgare* L. (1988). CW f. [Shoemaker].

#### Onagraceae

*Circaea lutetiana* L. ssp. *canadensis* (L.) Ascher & Magnus (1988).

*Epilobium coloratum* Biehler (1988). RM sb, CW sb, RM f, CW f.

*Ludwigia alternifolia* L. (1988). CW sb, CW f.

*Ludwigia palustris* (L.) Ell. (1988). RM sb, CW sb, RM f, CW f.

*Ludwigia peploides* (Kunth) Raven. (1988). CW f. Observed on Elatine Is. in CW during fall 2002; did not persist. Common at Sturgeon Pond.

*Oenothera biennis* L. (1988). RM sb, CW sb, CW f. [Abbott].

*Oenothera perennis* L. Bordentown Bluffs, sandy area near beach at Stanton Ave.

#### Orobanchaceae

*Epifagus virginiana* (L.) Bart.

*Orobanche uniflora* L. Uncommon; found once on abandoned road to forested island near Hamilton water treatment plant and RM.

#### Oxalidaceae

*Oxalis stricta* L. (1988). CW f.

*Oxalis violacea* L. Bordentown Bluffs; observed in 1992, but not in 2004. [Bonaparte].

#### Papaveraceae

\**Chelidonium majus* L. (1988).

#### Phytolaccaceae

*Phytolacca americana* L. (1988). CW sb, CW f. [Abbott].

#### Plantaginaceae

*Plantago aristata* Michx. (1988). CW f.

\**Plantago lanceolata* L. (1988). CW f. [Bonaparte].

\**Plantago major* L. CW sb.

*Plantago rugelii* Decne. (1988). CW f.

### Platanaceae

*Platanus occidentalis* L. (1988). CW sb, CW f. [Bonaparte] [Abbott] [Shoemaker].

### Polemoniaceae

*Phlox paniculata* L.

### Polygonaceae

*Polygonella articulata* (L.) Meisn. CW f.

*Polygonum amphibium* L. (1988). RM f, CW f. Sturgeon Pond west, Spring Lake; CW on Abbott Is. in 2004.

*Polygonum arifolium* L. (1988). RM sb, CW sb, RM f, CW f.

\**Polygonum aviculare* L. CW f.

\**Polygonum caespitosum* Blume. (1988). CW sb, CW f.

*Polygonum careyi* Olney. CW sb.

*Polygonum cilinode* Michx. CW f.

\**Polygonum cuspidatum* Sieb. & Zucc. (1988). CW f.

\**Polygonum hydroppiper* L. CW sb, CW f.

*Polygonum hydroppiperoides* Michx. (1988). CW sb, CW f.

*Polygonum lapathifolium* L. (1988). CW sb, CW f.

\**Polygonum orientale* L. (1988, Schuyler).

*Polygonum pennsylvanicum* L. (1988). CW sb, CW f.

\**Polygonum perfoliatum* L. CW f, a few plants at north inlet 2001, 2002, but not 2003).

\**Polygonum persicaria* L. CW sb, CW f.

*Polygonum punctatum* EIL. (1988). RM sb, CW sb, RM f, CW f.

*Polygonum sagittatum* L. (1988). RM sb, CW sb, RM f, CW f.

*Polygonum scandens* L. (1988). CW f.

*Polygonum setaceum* Baldw. ex Ell. S2. CW sb, CW f.

*Polygonum virginianum* L. (1988). RM f, CW f.

\**Rumex acetosella* L. CW f.

*Rumex altissimus* A.Wood. CW sb, CW f.

\**Rumex crispus* L. (1988). CW f.

\**Rumex obtusifolius* L. (1988). CW sb, CW f.

*Rumex triangulivalvis* (Danser) Rech.f.

### Portulacaceae

*Claytonia virginica* L. (1988). CW f. [Abbott] [Shoemaker].

*Portulaca oleracea* L. CW f.

### Primulaceae

\**Anagallis arvensis* L.

*Lysimachia ciliata* L. (1988). RM sb, CW sb, RM f, CW f.

\**Lysimachia nummularia* L. CW f.

*Lysimachia quadrifolia* L.

*Lysimachia terrestris* (L.) BSP. CW f.

### Pyrolaceae

*Chimaphila maculata* (L.) Pursh. (1988). Infrequent.

### Ranunculaceae

*Anemone quinquefolia* L. [Bonaparte] [Abbott+] [Shoemaker].

*Caltha palustris* L. (1988). Locally common in tidal areas near railroad (w) and Bordentown water plant. [Abbott].

\**Clematis terniflora* DC. (1988). CW sb, CW f. Common along upland edges near Delaware River.

*Ranunculus abortivus* L. (1988). CW f.

\**Ranunculus bulbosus* L. Lawn near edge of bluff at Point Breeze. [Abbott+].

\**Ranunculus ficaria* L. CW f. Well established along Delaware River in 2003, especially north of little mitigation site; first occurrence not noted. First observed in CW in 2001. Not recorded along Crosswicks Creek.

*Ranunculus hispidus* Michx. CW f.

*Ranunculus longirostris* Godr. (1988, Schuyler, herbarium only).

\**Ranunculus sceleratus* L. (1988). RM sb, RM f, CW f.

*Thalictrum pubescens* Pursh (1988). RM sb, RN f, CW f. [Abbott+] [Shoemaker].

### Rosaceae

*Agrimonia parviflora* Ait. CW f.

*Amelanchier arborea* (Michx.f.) Fern. Bordentown Bluffs.

*Aronia melanocarpa* (Michx.) Ell. Bordentown Bluffs along Crosswicks Creek.

*Crataegus crus-galli* L. *sensu lato* [Abbott+].

*Crataegus intricata* Lange *sensu lato*. Identified by J. Meyer.

\**Duchesnea indica* (Andr.) Focke

*Fragaria virginiana* P.Mill.

*Geum canadense* Jacq. (1988). CW f.

*Geum laciniatum* Murr. (1988, Arsenault). CW f.

\**Malus pumila* P.Mill. Infrequent, Crosswicks Creek floodplain. [Shoemaker].

*Physocarpus opulifolius* (L.) Maxim. (1988). RM sb, RM f, CW f.

*Potentilla norvegica* L. (1988). RM sb, CW sb, CW f.

\**Potentilla recta* L.

*Potentilla simplex* Michx. (1988). CW f.

*Prunus serotina* Ehrh. (1988). RM f, CW f. [Bonaparte] [Abbott+].

*Prunus serulata* (?) One small tree at the edge of Abbott's swamp.

\**Pyrus communis* L. Infrequent, Crosswicks Creek floodplain.

\**Rosa multiflora* Thunb. ex Murr. (1988). CW f.

*Rosa palustris* Marshall (1988). RM f.

\**Rosa spinosissima*. One bush, south tip of Duck Is.

*Rubus allegheniensis* Porter (= *Rubus pensilvanicus* Poir.) (1988). CW f. [Bonaparte] [Abbott].

*Rubus flagellaris* Willd. *sensu lato* [Shoemaker].

*Rubus hispidus* L. *sensu lato*.

\**Rubus laciniatus* Willd.

*Rubus occidentalis* L. [Shoemaker].

*Rubus odoratus* L. CW f; did not persist.

\**Rubus phoenicolasius* Maxim. (1988). CW f.

*Spiraea latifolia* (Ait.) Borkh. (1988). CW sb.

*Spiraea tomentosa* L. (1988).

### Rubiaceae

*Cephalanthus occidentalis* L. (1988). RM sb, CW sb, CW f. [Abbott].

*Diodia teres* Walt. CW f.

*Galium aparine* L. (1988). CW f. [Bonaparte]

*Galium obtusum* Bigel. (1988). RM f, CW f.

*Galium palustre* L. Identified by W. Standaert and P. Cooney.

*Galium tinctorium* L. (1988). CW sb.

*Galium triflorum* Michx.

*Hedyotis caerulea* (L.) Hook. (1988). CW f. [Bonaparte] [Abbott] [Shoemaker].

*Mitchella repens* L.

### Rutaceae

\**Phellodendron japonicum* Maxim. One tree, > 10 cm

DBH along trail near Sturgeon Pond east (chopped down).

*Ptelea trifoliata* L. CW f. Several locations on Duck Is.: open area north of CW, road to navigation beacon, and upland edge of west marsh, Lamber-ton Road.

#### Salicaceae

*Populus balsamifera* L.

*Populus deltoides* Bartr. ex Marsh.

*Populus grandidentata* Michx. (1988). CW f.

*Populus heterophylla* L. (1988). RM sb. One tree lo-cated from canoe along tidal channel near brick factory.

\**Populus nigra* L.

*Populus tremuloides* Michx. (1988).

\**Salix babylonica* L. Planted at Spring Lake. [Abbott].

*Salix bebbiana* Sarg. (1988). RM sb.

*Salix discolor* Muhl.

*Salix eriocephala* Michx. (1988). RM sb, RM f.

*Salix exigua* Nutt. CW f.

\**Salix fragilis* L. (1988, Arsenault).

*Salix humilis* Marshall (*S. tristis*?) (1988).

*Salix* hybrid (1988). RM sb.

*Salix nigra* Marshall. CW sb, CW f. [Shoemaker].

*Salix sericea* Marshall. CW f.

#### Sapindaceae

\**Koeleruteria paniculata* Laxm. Infrequent; along Delaware River.

#### Saururaceae

*Saururus cernuus* L. CW sb. Abbott's swamp and along Crosswicks Creek upstream of railroad bridge at Bordentown.

#### Saxifragaceae

*Heuchera americana* L. Bordentown Bluffs.

*Penthorum sedoides* L. (1988). CW sb, CW f.

#### Scrophulariaceae

*Agalinus purpurea* (L.) Pennell. [Abbott+].

*Chelone glabra* L. (1988). RM sb, RM f, CW f. at CW; did not persist.

*Gratiola neglecta* Torr. (1988). Rm sb, CW sb, RN f, CW f.

*Linaria canadensis* (L.) Dum.-Cours. (1988). CW f.

\**Linaria vulgaris* Hill. CW f.

*Lindernia dubia* (L.) Pennell (1988). CW sb, CW f.

\**Mazus pumilus* (Burm.f.) Steenis. CW f. Edge Dela-ware River near Trenton boat launch.

*Mimulus alatus* Ait. (1988, Schuyler). CW f. Frequent at CW, 1995-1997, but did not persist.

*Mimulus ringens* L. (1988). CW sb, CW f. Frequent at CW 1995-1997, infrequent later; also white form in 1995.

*Scrophularia marilandica* L. (1988). CW f.

\**Verbascum blattaria* L. (1988). CW f.

\**Verbascum lychnitis* L. CW f. Duck Is., upland north of CW; road to beacon.

\**Verbascum thapsus* L. (1988). CW sb, CW f.

*Veronica americana* (Raf.) Schwein. ex Benth. CW f.

*Veronica anagallis-aquatica* L. CW f.

\**Veronica arvensis* L.

\**Veronica hederifolia* L. Woods near Yardville.

\**Veronica longifolia* L. (1988, Blicharz).

*Veronica peregrina* L. (1988). RM sb, CW sb, RM f, CW f.

*Veronica persica* Poir. N. Community Park.

#### Simaroubaceae

\**Ailanthus altissima* (P.Mill.) Swingle (1988). CW sb, CW f. [Shoemaker].

#### Solanaceae

\**Datura stramonium* L. CW f. [Abbott].

\**Lycium barbarum* L. Near Sturgeon Pond during highway construction. Identified by D. Snyder.

*Physalis heterophylla* Nees. CW f.

*Physalis subglabrata* Mackenzie & Bush

*Solanum carolinense* L. CW f.

\**Solanum dulcamara* L. (1988). [Abbott].

*Solanum nigrum* L. (1988). CW sb, CW f.

#### Staphyleaceae

*Staphylea trifolia* L. Common, Crosswicks Creek floodplain.

#### Tiliaceae

*Tilia americana* L. (1988). CW f. [Abbott].

#### Ulmaceae

*Celtis occidentalis* L. (1988).

*Ulmus americana* L. CW f. [Abbott+].

\**Ulmus glabra* Hudson. Identified by J. Kuser.

*Ulmus rubra* Muhl. (1988). RM f, CW f.

#### Urticaceae

*Boehmeria cylindrica* (L.) Swartz (1988). RM sb, CW sb, RM f, CW f.

*Laportea canadensis* (L.) Weddell (1988). CW f.

*Pilea pumila* (L.) A.Gray (1988). RM sb, CW sb, RM f, CW f.

*Urtica dioica* L. ssp. *gracilis* (Ait.) Seland. CW f; on Tide Pool Is.

#### Valerianaceae

\**Valerianella locusta* (L.) Betcke. CW f. [Bonaparte] [Abbott].

#### Verbenaceae

*Verbena hastata* L. CW sb, CW f. [Abbott].

*Verbena urticifolia* L. (1988). CW f.

#### Violaceae

\**Viola arvensis* Murr.

*Viola lanceolata* L.

*Viola macloskeyi* Lloyd ssp. *pallens* (Banks ex DC) M.S.Baker

*Viola eriocarpa* Schwein.

*Viola rafinesquii* Greene (1988). CW f. [Shoemaker].

*Viola sororia* Willd. (1988). RM sb, RM f.

*Viola striata* Ait. Edge of lawn at bluff, Point Breeze.

#### Vitaceae

\**Ampelopsis brevipedunculata* (Maxim.) Trautv. CW f. Identified by P. Cooney.

*Parthenocissus quinquefolia* (L.) Planch. (1988). RM sb, RM f, CW f. [Abbott].

*Vitis aestivalis* Michx. (1988). RM f.

*Vitis labrusca* L. (1988). CW f. [Abbott].

*Vitis riparia* Michx. (1988). CW f.

*Vitis vulpina* L. CW f. [Abbott][Shoemaker].

*Vitis* sp. CW sb.

#### LILIOPSIDA (Monocotyledons)

#### Acoraceae

*Acorus calamus* L. (1988). RM f, CW f. Extensive stands in some high marsh areas, e.g., N. Community Park. Not observed to produce seeds.

#### Agavaceae

*Yucca flaccida* Haw. Spring Lake trail.

### Alismataceae

*Alisma plantago-aquatica* L. var. *parviflorum* (Pursh) Torr. (1988). RM sb, CW sb, RM f, CW f. [Abbott+].

*Sagittaria graminea* Michx. CW f.

*Sagittaria latifolia* Willd. (1988). RM sb, CW sb, RM f, CW f. [Abbott+] [Shoemaker].

*Sagittaria rigida* Pursh (1988, Schuyler).

*Sagittaria subulata* (L.) Buch (1988). CW f. Frequent; CW on islands and north and east marshes, and along Delaware River where it occurs as turf near low tide elevation.

### Araceae

*Arisaema dracontium* (L.) Schott. CW f. One mature plant, Delaware River floodplain beneath trees, near CW inlet.

*Arisaema triphyllum* (L.) Schott. (1988). [Shoemaker].

*Orontium aquaticum* L. (1988). About a dozen plants, upper intertidal on Crosswicks Creek (north bank); upstream and within sight of the Bordentown railroad bridge. One of two rarest species noted by Abbott (1887). [Abbott].

*Peltandra virginica* (L.) Schott & Endl. (1988). RM sb, RM f, CW f. [Abbott+] [Shoemaker].

*Symplocarpus foetidus* (L.) Salisb. ex Nutt. (1988). Common along bluffs in seepage areas. [Abbott+] [Shoemaker].

### Commelinaceae

\**Commelina communis* L. (1988). [Abbott].

*Tradescantia ohioensis* Raf. S2. Duck Is. along railroad.

*Tradescantia virginiana* L. Frequent along railroads on Duck Is. and near Yardville.

### Cyperaceae

*Bulbostylis capillaris* (L.) C.B. Clarke. CW f. Duck Is. along railroad.

*Carex abscondita* Mackenzie. CW f.

*Carex amphibola* Steud. CW f.

*Carex annectans* (Bickn.) Bickn. CW sb.

*Carex argyrantha* Tuckerman

*Carex blanda* Dewey. CW f.

*Carex brevior* (Dewey) Mackenzie ex Lunell. CW f.

*Carex canescens* L. CW sb, CW f.

*Carex caroliniana* Schwein. CW f.

*Carex cephalophora* Muhl. ex Willd. CW f.

*Carex comosa* Boott. CW f.

*Carex crinita* Lam. (1988). CW f.

*Carex cristatella* Britt. CW f.

*Carex davisii* Schwein. & Torr. CW f.

*Carex debilis* Michx. CW f.

*Carex festucacea* Schkuhr ex Willd.

*Carex frankii* Kunth. CW sb, CW f. Various terrestrial locations including upland north edge of CW, on islands, and near Bordentown beach.

*Carex granularis* Muhl. ex Willd. CW f.

*Carex grayi* Carey. (1988). CW f.

*Carex gynandra* Schwein.

*Carex hystericina* Muhl. ex Willd. CW f.

*Carex interior* Bailey

*Carex intumescens* Rudge (1988).

*Carex lacustris* Willd. (1988, Schuyler).

*Carex laevivaginata* (Kukenth.) Mackenzie

*Carex laxiculmis* Schwein. CW sb.

*Carex laxiflora* Lam. (= *Carex laxiculmis* Schwein.) CW sb.

*Carex lupulina* Muhl. ex Willd. (1988). CW f.

*Carex lurida* Wahlenb. CW sb, CW f.

*Carex molesta* Mackenzie ex Bright. CW f.

*Carex normalis* Mackenzie. CW f.

*Carex pellita* Muhl. ex Willd.

*Carex pennsylvanica* Lam. RM f.

*Carex projecta* Mackenzie (1988). CW sb.

*Carex radiata* (Wahlenb.) Small (1988). CW f.

*Carex rosea* Schkuhr. ex Willd. (1988, Arsenault).

*Carex scoparia* Schkuhr ex Willd. (1988). RM sb, CW sb, RM f, CW f.

*Carex squarrosa* L. (1988). CW f.

*Carex sterilis* Willd. CW sb, CW f.

*Carex stipata* Muhl. Ex Willd. (1988). RM sb, CW sb, CW f.

*Carex straminea* Willd. in Schkuhr (1988).

*Carex stricta* Lam. (1988). CW sb, CW f.

*Carex swanii* (Fern.) Mackenzie. (1988). RM sb, CW f.

*Carex tribuloides* Wahlenb. CW sb, CW f.

*Carex trichocarpa* Muhl. ex Willd. Identified by W. Olson.

*Carex trisperma* Dewey

*Carex vulpinoidea* Michx. (1988). CW sb, CW f.

*Cyperus bipartitus* Torr. CW sb, CW f. Pseudo-viviparous plantlets on greenhouse seed-bank specimen.

*Cyperus dentatus* Torr. (1988). CW sb, CW f.

*Cyperus diandrus* Torr. CW sb, CW f.

*Cyperus echinatus* (L.) A. Wood. (1988). CW f.

*Cyperus erythrorhizos* Muhl. (1988). RM sb, CW sb, CW f.

*Cyperus esculentus* L. CW sb.

*Cyperus flavescens* L. CW sb, CW f.

*Cyperus lancastris* Porter ex A. Gray. CW f.

*Cyperus lupulinus* (Sprengel) Marcks (1988). CW sb, CW f. Bordentown Bluffs, open sandy area near Stanton Ave.

\**Cyperus microiria* Steud. CW sb, CW f.

*Cyperus odoratus* L. CW sb, CW f.

*Cyperus retrofractus* (L.) Torr.

*Cyperus squarrosus* L. CW sb. (Only sb).

*Cyperus strigosus* L. (1988). RM sb, CW sb, RM f, CW f.

*Dulichium arundinaceum* (L.) Britt. (1988). RM sb, RM f, CW f.

*Eleocharis acicularis* (L.) Roemer & Schultes (1988). CW sb, CW f.

*Eleocharis engelmannii* Steud. CW sb, CW f.

*Eleocharis erythropoda* Steud. CW sb.

*Eleocharis obtusa* (Willd.) Schultes (1988). CW sb, CW f.

*Eleocharis palustris* (L.) Roemer & Schultes. CW sb, CW f.

*Eleocharis tenuis* (Willd.) Schultes

*Fimbristylis autumnalis* (L.) Roemer & Schultes. CW sb, CW f.

\**Kyllinga gracillima* Miq. CW sb, CW f.

*Rhynchospora capitellata* (Michx.) Vahl

*Schoenoplectus fluviatilis* (Torr.) Strong (1988). RM f, CW f.

*Schoenoplectus pungens* (americanus) (Vahl) Palla (1988). CW sb, CW f.

*Schoenoplectus purshianus* (Fern.) Strong. CW f. Pseudo-viviparous plantlets noted in the field.

*Schoenoplectus smithii* (A. Gray) Sojak. CW sb, CW f.

Frequent during early succession at CW; did not persist.

*Schoenoplectus tabernaemontani* (K.C.Gmel.) Palla.  
CW sb, CW f.

*Scirpus atrocinctus* Fern. CW f. Identified by A.E. Schuyler; did not persist.

*Scirpus atrovirens* Willd. CW f. Field vivipary noted.

*Scirpus cyperinus* (L.) Kunth. (1988). RM sb, CW sb, RM f, CW f.

*Scirpus expansus* Fern. CW f.

*Scirpus georgianus* Harper. CW f. Pseudo-viviparous plantlets noted in the field.

*Scirpus hattorianus* Makino. CW f.

*Scirpus polyphyllus* Vahl. (1988). CW f. Pseudo-viviparous plantlets noted in the field.

#### Dioscoriaceae

\**Dioscorea batatas* Decne. (1988). Near railroad bridge at Bordentown.

*Dioscorea villosa* L. (1988). RM sb, RM f.

#### Eriocaulaceae

*Eriocaulon parkeri* B.L.Robins (1988, Schuyler, herbarium only).

#### Hydrocharitaceae

\**Egeria densa* Planch. Small pond at N. Community Park in 2001.

*Elodea nuttallii* (Planch.) St. John (1988). CW f.

\**Hydrilla verticillata* (L. f.) Royle. CW f. First found in 2003; dense growth in Tide Pool. Identified by A.E. Schuyler.

*Vallisneria americana* Michx. (1988). CW f. Extensive beds along Delaware River from Bordentown to CW. [Abbott].

#### Iridaceae

\**Iris pseudoacorus* L. (1988). RM sb, RM f, CW f. [Abbott].

*Iris versicolor* L. (1988). CW f. [Abbott] [Shoemaker].

*Sisyrinchium angustifolium* P.Mill. (1988). CW f. [Shoemaker].

#### Juncaceae

*Juncus acuminatus* Michx. (1988). CW sb, CW f. Pseudo-viviparous plantlets in the field. frequent.

*Juncus brevicaudatus* (Engelm.) Fern. CW f. Identified by A.E. Schuyler. On Elatine Is. in 1996, did not persist.

*Juncus bufonius* L.

*Juncus dichotomus* Ell. CW f.

*Juncus effusus* L. (1988). RM sb, CW sb, RM f, CW f.

*Juncus secundus* Beauv. ex Poir. CW f.

*Juncus tenuis* Willd. (1988). RM sb. CW sb, RM f, CW f.

*Juncus torreyi* Cov. CW f. Identified by A.E. Schuyler in 1996; did not persist.

*Luzula multiflora* (Ehrh.) Lej. (1988).

#### Lemnaceae

*Lemna minor* L. (1988). RM sb, CW sb, RM f, CW f.

*Lemna valdiviana* Philippi. With other Lemnaceae, below surface during cool weather (e.g. Dec.). Six previous state records (D. Snyder, pers. commun.).

*Spirodela polyrhiza* (L.) Schleid. (1988). CW f.

*Wolffia columbiana* Karst. (1988). [Shoemaker].

*Wolffia papulifera* C. Thompson

*Wolffiella gladiata* (Hegelm.) Hegelm. Locally abundant in 2002-2003, edge of Sturgeon Pond (east)

and along the north and west marshes at Spring Lake. Four previous state records (D. Snyder pers com.).

#### Liliaceae

*Allium canadense* L. Woods at N. Community Park and near brick factory.

\**Allium vineale* L. (1988). CW f.

\**Asparagus officinalis* L. (1988).

\**Convallaria majalis* L.

*Erythronium americanum* Ker-Gawl. (1988). [Abbott] [Shoemaker].

\**Hemerocallis fulva* (L.) L. [Shoemaker].

\**Hosta* sp. (probably *H. ventricosa* (Salisb.) Stearn.) (1988).

*Lilium canadense* L. Frequent along Crosswicks Creek  
*Lilium superbum* L. (1988). CW f. [Abbott noted plants > 2 m tall].

*Maianthemum canadense* Desf. Locally abundant.

*Medeola virginiana* L. N. Community Park.

\**Narcissis pseudonarcissis* L. At abandoned homesites or planted. Near Watson House some single and doubled flowered plants, dating to 1915, were planted by Issac R. Van Zant (L. van Sant, pers. com.). [Abbott+].

\**Ornithogalum umbellatum* L. CW f. One plant noted at Bordentown Bluffs in 1993. [Bonaparte].

*Polygonatum biflorum* (Walt.) Ell. (1988). CW f. [Bonaparte] [Abbott+].

*Polygonatum biflorum* (Walt.) Ell. var. *commutatum* (Schultes f.) Morong [Shoemaker].

*Smilacina racemosa* (L.) Desf. (1988). CW f. [Bonaparte] [Shoemaker].

*Uvularia sessilifolia* L. (1988).

#### Najadaceae

*Najas flexilis* (Willd.) Rostk. & Schmidt. CW f.

#### Orchidaceae

*Cypripedium acaule* Ait. Once common, now only 5 isolated, widely scattered non-flowering plants (3 Bordentown Bluffs, 1 N. Community Park, and 1 near Sturgeon Pond east). [Abbott+].

\**Epipactis helleborine* (L.) Crantz. Infrequent, near brick factory (2001, 2002); also N. Community Park.

*Platanthera lacera* (Michx.) G.Don. One plant along Spring Lake trail, woods near Beaver Point (2002).

*Spiranthes cernua* (L.) L.C.Rich. Open area near Sturgeon Pond east (1991).

#### Poaceae

\**Agrostis capillaris* L. CW sb.

\**Agrostis gigantea* Roth. CW sb, RM f.

*Agrostis hyemalis* (Walt.) BSP. CW f.

*Agrostis perennans* (Walt.) Tuckerman. CW sb.

\**Agrostis stolonifera* L. (1988). RM sb, CW f.

\**Alopecurus pratensis* L.

*Andropogon gerardii* Vitman (1988). CW f.

*Andropogon ternarius* Michx. CW f. On D.O.T Is; did not persist.

*Andropogon virginicus* L. (1988). RM sb, CW sb.

\**Anthoxanthum odoratum* L.

*Aristida dichotoma* Michx. (1988).

*Aristida oligantha* Michx.

*Aristida purpurascens* Poir.

\**Arthraxon hispidus* (Thunb.) Makino (1988). CW sb,

- CW f. Dominant on terrestrial portions of several islands.
- Bromus ciliatus* L.  
 \**Bromus inermis* Leys. CW f.  
 \**Bromus japonicus* Thunb. ex Murr.  
 \**Bromus racemosus* L.  
 \**Bromus sterilis* L. CW f.  
 \**Bromus tectorum* L. CW f.  
*Calamagrostis canadensis* (Michx.) Beauv. CW f.  
 \**Cenchrus tribuloides* L.  
*Cinna arundinacea* L. (1988). RM sb, RM f.  
*Critesion jubatum* (L.) Nevski. (1988). CW f.  
 \**Dactylis glomerata* L. (1988). CW f.  
*Danthonia spicata* (L.) Beauv. ex Roemer & Schultes. CW f.  
*Deschampsia flexuosa* (L.) Trin.  
*Digitaria filiformis* (L.) Koel. CW sb, CW f.  
 \**Digitaria ischaemum* (Schreb. ex Schweig) Schreb. ex Muhl. CW sb, CW f.  
 \**Digitaria sanguinalis* (L.) Scop. (1988). CW sb, CW f.  
 \**Echinochloa crusgalli* (L.) Beauv. (1988). RM sb, CW sb, CW f. [Abbott+].  
*Echinochloa muricata* (Beauv.) Fern. CW f.  
*Echinochloa walteri* (Pursh) Heller (1988). RM sb, CW f.  
 \**Eleusine indica* (L.) Gaertn. (1988). CW f.  
*Elymus hystrix* L. (1988).  
*Elymus villosus* Muhl. ex Willd.  
*Elymus virginicus* L. (1988).  
 \**Elytrigia repens* (L.) Desv. ex Nevski. CW f.  
*Eragrostis capillaris* (L.) Nees  
 \**Eragrostis cilianensis* (All.) Hubbard. CW f.  
 \**Eragrostis curvula* (Schrader) Nees. CW f.  
*Eragrostis hypnoides* (Lam.) BSP. (1988). CW f.  
*Eragrostis minor* Host  
*Eragrostis pectinacea* (Michx.) Nees. CW sb, CW f.  
 \**Eragrostis pilosa* (L.) Beauv. CW sb, CW f.  
*Eragrostis spectabilis* (Pursh) Steud. (1988). CW sb, CW f.  
 \**Festuca elatior* L.  
*Festuca obtusa* Biehler  
*Festuca ovina* L.  
*Festuca pratensis* Huds.  
*Festuca rubra* L. (1988). CW f.  
*Glyceria canadensis* (Michx.) Trin. CW f.  
*Glyceria melicaria* (Michx.) F.T.Hubbard. CW f.  
*Glyceria obtusa* (Muhl.) Trin.  
*Glyceria septentrionalis* A.S.Hitchc. (1988).  
*Glyceria striata* (Lam.) A.S.Hitchc. (1988). RM sb, RM f, CW f.  
 \**Holcus lanatus* L. CW f.  
*Leersia oryzoides* (L.) Swartz (1988). RM sb, CW sb, RM f, CW f.  
*Leersia virginica* Willd. (1988). CW sb, CW f.  
*Leptoloma cognatum* (Schultes) Chase. CW f.  
 \**Lolium multiflorum* Lam. CW f.  
 \**Lolium perenne* L. (1988). CW f.  
*Melica mutica* Walter  
 \**Microstegium vimineum* (Trin.) A.Camus. (1988). RM sb, CW sb, RM f, CW f. Common in some locations in CW, e.g., D. Cross Is. under woody canopy in 2004 where it is apparently replacing Cyperaceae.  
 \**Miscanthus sinensis* Anderss.  
*Muhlenbergia schreberi* J.F.Gmel. CW f.  
*Panicum acuminatum* Swartz. CW sb.  
*Panicum anceps* Michx. (1988).  
*Panicum capillare* L. CW sb, CW f.  
*Panicum clandestinum* L. (1988). CW sb, CW f.  
*Panicum columbianum* Scribn. CW f.  
*Panicum commutatum* Schultes  
*Panicum dichotomiflorum* Michx. (1988). RM sb, CW sb, CW f.  
*Panicum dichotomum* L.  
*Panicum latifolium* L. (1988). CW f.  
*Panicum stipitatum* Nash. (1988, Schuyler).  
*Panicum verrucosum* Muhl. CW f.  
*Panicum virgatum* L. (1988). RM f, CW f.  
*Paspalum laeve* Michx.  
*Paspalum setaceum* Michx. var. *muhlenbergii* (Nash) D.Banks  
*Phalaris arundinacea* L. (1988). RM sb, CW sb, RM f, CW f.  
 \**Phleum pratense* L. [Abbott].  
*Phragmites australis* (Cav.) Trin. ex Steud. (1988). RM sb, CW sb, RM f, CW f. Present at CW in 1994; cover increasing. [Abbott+, "feathery reed"].  
 \**Poa annua* L.  
 \**Poa compressa* L. (1988).  
*Poa palustris* L.  
 \**Poa pratensis* L. CW f.  
 \**Poa trivialis* L. (1988). RM sb, CW sb, RM f, CW f. Pseudo-viviparous plantlets noted on greenhouse seed-bank specimen. [Abbott].  
*Schizachyrium scoparium* (Michx.) Nash (1988). CW f.  
 \**Setaria faberi* Herrm. (1988). CW f.  
 \**Setaria pumila* (Poir.) Schultes (1988).  
*Setaria viridis* (L.) Beauv. CW f.  
*Sorghastrum nutans* (L.) Nash (1988). CW f.  
*Spartina pectinata* Link (1988, Schuyler, herbarium only).  
*Torreyochloa pallida* (Torr.) Church (1988, Schuyler).  
*Tridens flavus* (L.) A.S.Hitchc. (1988).  
 \**Vulpia myuros* (L.) K.C.Gmel. var. *myuros*  
*Zizania aquatica* L. var. *aquatica* (1988). RM sb, RM f, CW f. [Abbott].
- Pontederiaceae**  
*Heteranthera multiflora* (Griseb.) Horn. (1988). CW sb, RM f, CW f. Observed at the Spring Lake spillway, at CW, and elsewhere. Appears to be more frequent than *H. reniformis*.  
*Heteranthera reniformis* Ruiz & Pavon (1988). RM f, CW f.  
*Pontederia cordata* L. (1988). RM sb, CW sb, RM f, CW f. [Abbott] [Shoemaker].
- Potamogetonaceae**  
 \**Potamogeton crispus* L. RM f, CW f.  
*Potamogeton diversifolius* Raf. (1988). [Schuyler].  
*Potamogeton epihydrus* Raf. (1988).  
*Potamogeton pectinatus* L. (1988).  
*Potamogeton pusillus* L. CW f.
- Smilacaceae**  
*Smilax glauca* Walt.  
*Smilax pseudochina* L. Floodplain along Duck Creek.  
*Smilax pulverulenta* Michx. (1988). RM f, CW f. *S. pulverulenta* var. *pulverulenta*. near Sturgeon Pond, identified by D. Snyder.  
*Smilax rotundifolia* L. (1988). RM f, CW f. [Abbott] [Shoemaker].
- Sparganiaceae**  
*Sparganium americanum*, Nutt. (1988).  
*Sparganium eurycarpum* Engelm. (1988). CW f.

**Typhaceae**

*Typha angustifolia* L. (1988). RM f, CW f. [Shoemaker].

*Typha latifolia* L. (1988). RM sb, CW sb, RM f, CW f. [Abbott] [Shoemaker].

*Typha x glauca* Godr. FWC. CW f. Identified by A.E. Schuyler in 1996.

**Zannichelliaceae**

*Zannichellia palustris* L.

**CULTIVATED EPHEMERALS:****Araceae**

\**Pistia stratiotes* L. Spring Lake; did not persist.

**Asteraceae**

\**Tagetes erecta* L.

**Cannabaceae**

\**Cannabis sativa* L. Planted and escaped (?), three locations.

**Capparidaceae**

\**Cleome spinosa* L.

**Convolvulaceae**

\**Ipomoea coccinea* L.

\**Ipomoea purpurea* (L.) Roth

**Cucurbitaceae**

\**Citrullus colocynthis* (L.) Shrad. Waif.

**Polygonaceae**

\**Fagopyrum sagittatum* Gilib. (1988, Blicharz).

**Solanaceae**

\**Petunia X hybrida* Vilm.

**Poaceae**

\**Secale cereale* L.

\**Zea mays* L.

**Pontederiaceae**

\**Eichhornia crassipes* (Martius) Solms-Laub. Spring Lake several years; flowering observed but did not overwinter.

**Appendix 2.**

Plants noted by Bonaparte (1824), Abbott (1886, 1887, 1892, 1897, 1898), and by Shoemaker (1964) that are not presented in Appendix 1. The lack of an author citation means that there is no current synonym in Rhoads and Klein (1993), Gleason and Cronquist (1991), nor in Gray (1887). For the Abbott (1887) species, as in Appendix 1, no date is given; if they were listed in Leck et al. (1988), the date is indicated. Other Abbott citations are [Abbott+]. Each author mentions other species for which the specific name cannot be determined (e.g., *Cyperus* or *Lemna*); those are omitted. Taxonomy reflects Rhoads and Klein (1993) if possible. A (?) for certain Bonaparte species relates to difficulties interpreting hand written entries.

**Bonaparte (1824):**

*Andromeda racemosa* (?) Perhaps this is *Leucothoe racemosa* (L.) A. Gray, which is noted by Abbott (1898).

*Aquilegia canadensis* L. Growing on rocks of the grotto at Point Breeze (2004), but not observed elsewhere. [Abbott+].

*Aster patens* Ait.

*Betula papyrifera* Marshall

*Castanea vesca*

*Cornus stricta* Lam.

*Crateagus coccinea* L.

*Erangianus americanus* (?). Perhaps *Fraxinus americanus*. ("A small one was located in front of the Lake House and a superb one at old Point Breeze" (Old Point Breeze was the first Bonaparte mansion that burned down; a second was built a short distance away).

*Euphorbia specanalia* (?)

*Fagus sylvatica*

*Hypoxis erecta* L. In Gray (1887), possibly *H. hirsuta* (L.) Cov.

*Juglans porcina*. In Gray (1887) *Carya porcina* Nutt. is pignut hickory, which in Gleason and Cronquist (1991) is *Carya glabra* (Miller) Sweet).

*Lycium carolinianum* (?)

*Myosotis scorpioides* L. [Abbott+].

*Oxalis corniculata* L.—"Great quantity in grass, in woods, and around the aviary."

*Philadelphus inodorus* L.

*Potentilla canadensis* L. Only this species is mentioned in Gray (1887), but Gleason and Cronquist (1991) would suggest this to be *P. simplex* Michx. 'Great quantity in woods'.

*Pyrus coronaria* L.

*Quercus aquatica* Walter. In Gray (1887) this is Water Oak, which is now *Q. nigra* L. [Shoemaker].

*Quercus tinctoria* Gray. In Gray (1887) this is Scarlet Oak, which is now *Q. coccinea* Muenchh. [Shoemaker].

*Robinia viscosa* Vent.

*Rosa parviflora* Perhaps *Rubus parviflorus* Nutt., thimbleberry.

*Rubus procumbens* (?)

*Salix laeagailla* (?)

*Salvia officinalis* L. Cultivated for the kitchen.

*Saxifraga virginica*. Probably *S. virginiensis* Michx. [Abbott+].

*Spirea opulifolia*. Cultivated?

*Syringa persica* L. Cultivated.

*Syringa vulgaris* L. Cultivated.

*Viola palmata* L.

*Viola pedata* L.

**Appendix 2.**

Continued.

**Abbott** (authorities generally are those provided by Abbott (1887); others are from Gray (1887)):

- Amelanchier canadensis* (L.) Medic. [Abbott+]  
*Anemone nemorosa* [Abbott+].  
*Aureolaria flava* (L.) Farw. var. *flava* (Abundant enough to pick an armful).  
*Brasenia schreberi* J.F. Gmel. Old Mercer Co. record (Hough 1983). [Shoemaker].  
*Castanea pumila* (L.) P. Mill.  
*Celastrus scandens* L.  
*Clematis virginiana* L. (1988)  
*Cydonia vulgaris* (Quince). [Abbott+].  
*Juglans cinerea* L.  
*Leucothoe racemosa* (L.) A. Gray [Abbott+].  
*Muscari botryoides* (L.) Miller. [Abbott+].  
*Polemonium caeruleum* L. [Abbott+].  
*Populus diletata* (= *P. nigra* L.). [Abbott+].  
*Prunus americana* Marshall  
*Prunus spinosa* ("Wild plum") [Abbott+].  
*Rhus venenata* (= *Toxicodendron vernix* (L.) Kuntze) [Abbott+].  
*Ribes grossularia* (= *R. uva-crispi* L.) [Abbott+].  
*Rosa virginiana* P. Mill.  
*Rubus canadensis* L.  
*Rubus villosa* Ait. In Gray (1887) called Common Blackberry, which is now *R. allegheniensis* T.C. Porter.  
*Sabatia angularis* (L.) Persh  
*Salix purpurea* L. Plantation noted.  
*Sanguinaria canadensis* L. [Abbot+].  
*Sisyrinchium burmudiana* Gray (= *S. anceps* Cav.) [Abbott+].  
*Thalictrum anemonoides* Michx. (= *Anemonella thalictroides* Spach. = *T. thalictroides* (L.) Eames & B. Boivin) [Abbott+] [Shoemaker].  
*Trichochloa capillaris* ("Meadow comb grass").  
*Uvularia perfoliata* L.  
*Viola cucullata* Aiton. [Abbott+].  
*Viola* spp. (White, yellow, purple) [Shoemaker].  
*Vitis labrusca* × *riparia*

**Shoemaker:**

- Actaea pachypoda* Ell. Hough (1983) notes this as rare on the inner coastal plain.  
*Baptisia tinctoria* (L.) Vent.  
*Euphorbia marginata* Pursh  
*Iris prismatica* Pursh  
*Solidago odora* Ait. Old Mercer Co. record (Hough 1983).  
*Viola ricolor* L.
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**Appendix 3.**

Species planted at the Duck Island constructed wetland between 1993 and 1995 by New Jersey Department of Transportation. Species designated with an \* were not previously found in the study area. Author citations for species occurring in Appendix 1 are not given here.

Herbaceous	Woody
<i>Acorus calamus</i>	<i>Acer rubrum</i>
<i>Iris pseudacorus</i>	<i>Amelanchier canadensis</i>
<i>Iris versicolor</i>	* <i>Aronia arbutifolia</i> (L.)
<i>Leersia oryzoides</i>	Ell.
<i>Nymphaea odorata</i>	<i>Aronia melanocarpa</i>
<i>Peltandra virginica</i>	<i>Cephalanthus occiden-</i>
<i>Pontederia cordata</i>	<i>talis</i>
<i>Potamogeton pectinatus</i>	* <i>Chionanthus virginicus</i> L.
<i>Sagittaria latifolia</i>	<i>Clethra alnifolia</i>
<i>Scirpus americanus</i>	<i>Cornus amomum</i>
( <i>Schoenoplectus pun-</i>	<i>Cornus sericea</i>
<i>gens</i> )	<i>Fraxinus pennsylvanica</i>
<i>Sparganium eurycarpum</i>	<i>Hibiscus moscheutos</i>
<i>Vallisneria americana</i>	* <i>Ilex glabra</i> (L.) A. Gray
<i>Zizania aquatica</i>	<i>Ilex verticillata</i>
	<i>Lindernia benzoin</i>
	<i>Liquidambar styraciflua</i>
	<i>Magnolia virginiana</i>
	<i>Nyssa sylvatica</i>
	<i>Platanus occidentatus</i>
	<i>Quercus palustris</i>
	<i>Sambucus canadensis</i>
	<i>Vaccinium corymbosum</i>
	<i>Viburnum dentatum</i>
	* <i>Viburnum lentago</i> L.
	* <i>Viburnum opulus</i> L.