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DISTRICT DEPARTMENT
OF THE ENVIRONMENT

ANACOSTIA RIVER FRINGE WETLANDS RESTORATION PROJECT

Final Report for the Five-Year Monitoring Program (2003 through 2007)

ON THE COVER

Aerial photograph of Anacostia River Fringe Wetlands Restoration from the north.
DDOE photo

ANACOSTIA RIVER FRINGE WETLANDS RESTORATION PROJECT

District Department of the Environment
51 N Street, NE 6th Floor
Washington, DC 20002

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Contributors

Cairn C. Krafft
USGS Patuxent Wildlife Research Center
Beltsville Lab, BARC-East 308
10300 Baltimore Avenue
Beltsville, Maryland 20705
(301) 497-5546
cairn_krafft@usgs.gov

Richard S. Hammerschlag, Scientist Emeritus
USGS Patuxent Wildlife Research Center
Beltsville Lab, BARC-East 308
10300 Baltimore Avenue
Beltsville, MD 20705
(301) 497-5555
rhammerschlag@usgs.gov

Glenn R. Guntenspergen
USGS Patuxent Wildlife Research Center
Laurel, Maryland 20706
(218) 720-4307
glenn_guntenspergen@usgs.gov

EXECUTIVE SUMMARY:

The 6-hectare (ha) freshwater tidal Anacostia River Fringe Wetlands (Fringe Wetlands) were reconstructed along the mainstem of the Anacostia River in Washington, DC (Photograph 1, Figure 1) during the summer of 2003. The Fringe Wetlands consist of two separate planting cells. Fringe A, located adjacent to Lower Kingman Island, on the west bank of the Anacostia River, occupies 1.6 ha; Fringe B, located on the east bank of the Anacostia River, occupies 4.4 ha.

This project is the third in a series of freshwater tidal wetland reconstructions on the Anacostia River designed and implemented by the US Army Corps of Engineers (USACE) Baltimore District and District Department of the Environment (DDOE) on lands managed by the National Park Service (NPS). The first was Kenilworth Marsh, reconstructed in 1993 (Syphax and Hammerschlag 2005); the second was Kingman Marsh, reconstructed in 2000 (Hammerschlag et al. 2006). Kenilworth and Kingman were both constructed in low-energy backwaters of the Anacostia. However, the Fringe Wetlands, which were constructed on two pre-existing benches along the high-energy mainstem, required sheet piling to provide protection from erosive impacts of increased flow and volume of water associated with storm events during the establishment phase (Photograph 2). All three projects required the placement of dredged sediment materials to increase elevations enough to support emergent vegetation (Photograph 3). The purpose of all three wetland reconstruction projects was to restore pieces of the once extensive tidal freshwater marsh habitat that bordered the Anacostia River historically, prior to the dredge and fill operations and sea wall installation that took place there in the early to mid-1900's (Photograph 4).

As the third in a series, the Fringe Wetlands Restoration Project benefited from lessons learned at the prior reconstructions. An extensive system of fencing, horizontal stringing, and flagging was installed (Photograph 5) to prevent extensive herbivory by resident Canada geese (*Branta canadensis*) instrumental in the decimation of vegetation at the Kingman Marsh site. Prior work at the Kenilworth and Kingman Marsh restoration sites indicated that numerous volunteer species successfully established in the restored areas. Based on these experiences, a much smaller number of species were included on the Fringe Wetlands planting list, which consisted of seven native plant species. Seventy-five percent of the approximately 350,000 plants placed at the Fringe Wetlands consisted of two species, *Peltandra virginica* (green arrow arum) and *Schoenoplectus tabernaemontani* (softstem bulrush), both of which had proven less palatable to Canada geese at Kingman Marsh. Elevations were targeted at 1.6 - 2.0 ft NGVD '29 (low/mid-marsh) to reduce the threat from *Phragmites australis* (common reed), an invasive exotic that eventually required herbicidal spraying at the Kenilworth Marsh restoration, and which was shown at Kingman Marsh to be absent from plots at elevations less than 2.1 ft NGVD '29 (Neff 2002).

The US Geological Survey's Patuxent Wildlife Research Center has participated in the monitoring of all three of the reconstruction sites, with a variety of partners including the District Department of the Environment (which designed the monitoring protocol for the

Fringe Wetlands and has provided partial funding for the monitoring), USACE (which provided partial funding for the work), NPS, University of Maryland, and the Anacostia Watershed Society, which has contributed extensive fenced plantings of *Zizania aquatica* (annual wildrice).

The Fringe Wetlands have been monitored for five years post-reconstruction, 2003 through 2007. A number of indicator metrics have been used to permit evaluation of the success of the wetland restoration. Many of these metrics were compared with results from Kenilworth Marsh and Kingman Marsh, the previous Anacostia wetland restorations, and Dueling Creek, an urban Anacostia reference wetland.

The elevation of the marsh surface in the Fringe Wetlands plots measured in 2006 covered a fairly broad range, with Fringe A elevations ranging from 1.48 to 2.39 ft and averaging 1.90 ± 0.08 ft and Fringe B coming in significantly higher, ranging from 1.76 to 3.24 ft and averaging 2.36 ± 0.06 ft. Based on a mean high tide of 2.2 ft NGVD '29, this translates into Fringe A consisting of low and mid-marsh elevations, and Fringe B consisting of mostly mid- and high marsh elevations. By way of comparison, elevations at Fringe A plots match fairly well with early Kingman Marsh elevations, with the significant exclusion of the lowest group of elevations measured at Kingman. Fringe B plot elevations overlapped with those at Fringe A, but were more similar to those measured at Kenilworth Marsh, suggesting that like Kenilworth, Fringe B will probably be more vulnerable to invasion by the exotic, *Phragmites australis*. Recognizing this vulnerability, NPS has already initiated control measures for *Phragmites* at Fringe B by spraying with herbicide in the fall of 2007. Continued monitoring is recommended for *Phragmites australis*, *Lythrum salicaria* (purple loosestrife), and *Murdannia keisak* (wartremoving herb/marsh dewflower), the three invasive exotics of special concern observed at the Fringe Wetlands at sub-dominant levels.

One hundred and forty-one species have been observed at the Fringe Wetlands, compared to 137 species at Kenilworth Marsh, 151 at Kingman Marsh, 92 at a created tidal freshwater wetland on the Delaware River (Leck 2003), and 50 to 60 species cited as the norm for natural tidal freshwater wetlands (Odum et al. 1984).

Shannon's diversity index averaged 1.49 ± 0.05 at the Fringe Wetlands in 2007, providing a striking contrast to the 0.39 ± 0.07 observed at Kingman in its fifth year, and also comparing favorably to the values for Dueling Creek, an Anacostia reference wetland, whose averages ranged from 1.20 ± 0.09 to 1.45 ± 0.06 during the five years (2001 – 2005) it was monitored with Kingman Marsh.

Total vegetative cover remained high at the Fringe Wetlands in 2007 (Photograph 6), with 98 % of the cover provided by wetland plants and 95 % of the cover provided by native species. In 2007 nine species met the criterion for dominant species at the Fringe Wetlands by providing at least 5 % cover in at least one season. Although Fringe A and Fringe B exhibited significant differences in cover levels for some of the dominant species earlier in the project, by 2007, the two areas no longer differed significantly with respect to cover levels for the nine remaining dominants. Of these nine dominant species, four were planted, all are species typically found in wetlands, and all are native. By contrast, only four species met the criterion for dominant species at Kingman after five years, and two of them were invasive exotics. Numbers of dominant species at Dueling Creek varied by year and ranged from six to ten species. Of the eleven dominants observed at Dueling Creek, all were typical wetland plants and ten of the eleven were natives.

Planted and volunteer species have each made significant contributions to cover at the Fringe Wetlands. As cover contributed by planted species has gradually declined, cover from volunteer species has gradually increased, showing that the Fringe Wetlands are providing a favorable habitat for the establishment of a wide array of typical wetland species that were either present in the seedbank or were dispersed into the site from tidal water, wind, or animals. The two planted species that have provided the most significant persistent cover are *Peltandra virginica* (green arrow arum), planted in 2003, and *Zizania aquatica* (annual wildrice), planted as seed in 2004 by the Anacostia Watershed Society (Photograph 7). *Sagittaria latifolia* (broadleaf arrowhead), also planted in 2003, has maintained its status as a dominant species for all five years (Photograph 8), but appears to be undergoing a significant decline.

In conclusion, indicator metrics for the Fringe Wetlands resemble those measured at an Anacostia reference wetland and the previous Anacostia wetland reconstruction efforts (prior to resident Canada goose herbivory). Total vegetative cover and species diversity and richness remain high in 2007 and do no differ significantly between Fringe A and Fringe B. Resident Canada goose herbivory has not decimated the vegetation, as at Kingman Marsh. Additional research would be needed to determine whether the relative absence of goose herbivory at the Fringe Wetlands is due to a more favorable geographic location (not surrounded by golf course), the presence of sheet piling (severely restricting goose access from the river), the presence of a goose deterrent system of fencing, horizontal stringing, and flagging, which was retained for five years (compared to a more limited system of fencing that was removed from Kingman Marsh after the first winter), or a combination of factors. Continued monitoring is recommended for the three exotic invasive species of concern which have remained at subdominant levels for the first five years of the Fringe Wetlands project. Interior fencing was removed from some of the higher elevation transects in December 2007. Additional fence removal activities are planned. Removal of the sheet piling is currently under consideration. Given the uncertainty in vegetation response to potential increased erosion and herbivory associated with removal of the sheet piling and fencing, it is our recommendation that monitoring be continued for at least three years after the sheet piling is removed to evaluate the impact of the management actions.

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INTRODUCTION:

The 6-hectare (ha) freshwater tidal River Fringe Wetlands (Fringe Wetlands) was reconstructed along the mainstem of the Anacostia River in Washington, DC (Photograph 1, Figure 1) during the summer of 2003. The Fringe Wetlands consist of two separate planting cells. Fringe A, located adjacent to Lower Kingman Island (west bank of the Anacostia), occupies 1.6 ha; Fringe B, located on the east bank of the Anacostia River, occupies 4.4 ha.

This project is the third in a series of freshwater tidal wetland reconstructions on the Anacostia River designed and implemented by the US Army Corps of Engineers (USACE) and District Department of the Environment (DDOE) on lands managed by the National Park Service (NPS). The first was Kenilworth Marsh, reconstructed in 1993 (Syphax and Hammerschlag 2005); the second was Kingman Marsh, reconstructed in 2000 (Hammerschlag et al. 2006). Kenilworth and Kingman were both constructed in low-energy backwaters of the Anacostia, unlike the Fringe Wetlands, which were constructed on two pre-existing benches along the high-energy mainstem, and therefore required sheet piling to provide protection from erosive impacts of increased flow and volume of water associated with storm events during the establishment phase (Photograph 2). All three projects required the placement of dredged sediment materials to increase elevations enough to support emergent vegetation (Photograph 3). The purpose of all three wetland reconstruction projects was to restore pieces of the once extensive tidal freshwater marsh habitat that bordered the Anacostia River historically, prior to the dredge and fill operations and sea wall installation that took place there in the early to mid-1900's (Photograph 4).

As the third in a series, the Fringe Wetlands Restoration Project benefited from lessons learned at the prior reconstructions. An extensive system of fencing, horizontal stringing, and flagging (Photograph 5) was installed to prevent the extensive herbivory by resident Canada geese instrumental in the decimation of vegetation at the Kingman Marsh site. Prior work at the Kenilworth and Kingman Marsh restoration sites indicated that numerous volunteer species successfully established in the restored areas. Based on this experience, a much smaller number of species was included on the Fringe Wetlands planting list (Table 1), which consisted of seven native plant species. Seventy-five percent of the approximately 350,000 plants put in at the Fringe Wetlands consisted of two species, *Peltandra virginica* (green arrow arum) and *Schoenoplectus tabernaemontani* (softstem bulrush), both of which had proven less palatable to Canada geese (*Branta canadensis*) at Kingman Marsh. Elevations were targeted at 1.6 - 2.0 ft NGVD '29 (low/mid-marsh) to reduce the threat from *Phragmites australis*, an invasive exotic that eventually required herbicidal spraying at the Kenilworth Marsh restoration, and which was shown at Kingman Marsh to be absent from plots at elevations less than 2.1 ft NGVD '29.

The US Geological Survey's Patuxent Wildlife Research Center has participated in the monitoring of all three of the reconstruction sites, with a variety of partners including the District Department of the Environment (which designed the monitoring protocol for the Fringe Wetlands and has provided partial funding for the monitoring), USACE (which provided partial funding for the work), NPS, University of Maryland, and the Anacostia Watershed Society, which has contributed extensive fenced plantings of *Zizania aquatica* (annual wildrice).

This final report examines the data from all five years of vegetation monitoring conducted at the Fringe Wetlands from 2003 through 2007. Comparisons are made with data from the previous Anacostia wetland restorations and Dueling Creek, an Anacostia reference wetland monitored during the Kingman project. Evaluations also compare data from Fringe A and Fringe B to determine the significance of differences between the two spatially-separated planting cells that constitute the Fringe Wetlands. The following parameters were monitored and used as indicators to evaluate the performance of the marsh reconstruction: elevation, total vegetative cover, species richness, diversity and evenness, cover contributed by various groups of species (typical wetland plants and typical upland plants, planted and volunteer species, natives and exotics, annuals and perennials), dominant species, the relationships between total vegetative cover and elevation as well as species richness and elevation, and the elevation ranges associated with key dominant species along with three exotic species of special concern.

METHODS:

Quantitative vegetation sampling was conducted in 48 1m by 2m plots located randomly along 12 transects oriented perpendicular to the shoreline. The parallel transects were located roughly equidistant along the length of the wetlands. Four transects were allocated to the 1.6-ha Fringe A, while eight transects were allocated to the 4.4-ha Fringe B (Figure 1). Four sampling plots were monitored per transect.

Elevations were obtained for each plot in 2006 using a surveyor's level pegged to benchmarks installed by USACE. Waiting until 2006 permitted for consolidation of the newly-placed dredge sediments to occur. In 2007, elevations were obtained for all plots in Fringe A, and most of the plots in Fringe B. A subset of plots in Fringe B was not sampled in 2007 due to the high volume of tall volunteer species it would have been necessary to remove from the wetland to clear the lines of sight needed for the surveying. Elevation data are provided in units of ft NGVD '29 (National Geodetic Vertical Datum based on mean tide levels nationally in the 1929 timeframe).

Percent cover within the 1m by 2m sampling frame was determined using ocular estimation. Calibrations between samplers were performed frequently. Data was collected by species or to the nearest known taxon. Total vegetative cover represents the sum of the cover values for the various taxa present, and may therefore total more than 100% where multiple strata of vegetation are present. Quantitative sampling was conducted seasonally during spring (mostly mid-late May), summer (mid-late July) and fall (mostly mid-September), with the following exceptions: in 2003 timing of the plantings meant that sampling could only be conducted in the fall; sampling was not conducted during the summer of 2004; and in 2007 the spring sampling event was replaced by a walk through, after it was decided that the combination of summer and fall sampling events provided the most representative snapshots of plant activity in the marsh. Species observed outside of the sampling plots were noted for the overall species list provided in the Appendix.

Taxonomic identifications were made using Brown and Brown (1984). Final nomenclature followed the US Department of Agriculture PLANTS database (USDA, NRCS 2008). Species classifications regarding US Fish and Wildlife Service Wetland Indicator Status, origin (native versus introduced/exotic), duration (annual versus perennial) and life form follow the PLANTS database, except where it was possible to obtain a more localized duration classification for species PLANTS characterized with a range of durations (e.g., annual/perennial). In cases where Brown and Brown did not clarify the situation, species listed by PLANTS as having a range of durations that included biennial and/or perennial were all treated as perennials for purposes of the analysis. Because of the difficulty in consistently distinguishing vegetative *Typha latifolia* (broadleaf cattail) from *Typha glauca*, its hybrid with *Typha angustifolia* (narrowleaf cattail), the decision was made to fold suspected hybrids in with the *Typha latifolia* data. *Typha angustifolia* data was reported separately.

Statistical Methods

Vegetation data were analyzed using a mixed model repeated measures analysis of variance (SAS, 2003, PROC MIXED) comparing the data among areas, years, and seasons within years. Pairwise comparisons were made using Tukey's Studentized Range Test of Least Squares Means (family-wise error rate with $\alpha = 0.05$). These analyses were conducted on the following dependent variables: total vegetative cover (the sum of cover values from individual species or other taxa), species richness (the number of species observed per 2 m^2 plot), Shannon's diversity and evenness indices, and cover by wetland and upland plants, planted and volunteer species, natives and exotics, and annuals and perennials, and individual dominant species and species of special concern. Statistical significance of cover provided by planted and volunteer species was determined by examining the *p*-values for the null hypothesis that Least Squares Means equaled 0. Bonferroni corrections were applied to these multiple comparisons. Elevation data were analyzed using a mixed model repeated measures analysis of variance (ANOVA) comparing data between areas and years.

Prior to analysis, data sets were tested to determine whether an unstructured model (which allows correlation between any two periods to be different) or compound symmetry model (which assumes the same correlation between any two time periods) produced better fit based on a lower value for Akaike's Information Criterion (AIC). Natural log transformation was used to improve normality of the data sets for richness, cover by individual species, and cover by annuals and exotics. Graphs and discussion present arithmetic means ± 1 standard error (SE), which avoids the problems inherent with back-transformation (Sokal and Rohlf 1981).

Dominant species were identified for each area as those species with an arithmetic mean + 1 SE of at least 5 % in at least one seasonal sampling event. Dominant species are graphed as arithmetic means ± 1 SE.

Diversity was calculated using the Shannon diversity index (Kent and Coker 1992):

Diversity $H' = -\sum_{i=1}^{s} p_i \ln p_i$

Evenness was calculated using the Shannon evenness index (Kent and Coker 1992):

Evenness $J = \frac{H'}{H'_{\max}} = \frac{\sum_{i=1}^{s} p_i \ln p_i}{\ln s}$

In both cases s = number of species
p_i = proportion of individuals or the abundance of the *i*th species expressed as a proportion of total cover
ln = natural logarithm.

Linear regression analyses were performed for total vegetative cover versus elevation and species richness versus elevation ($\alpha = 0.05$).

RESULTS AND DISCUSSION:

Results of the repeated measures analysis of variance tests are summarized in Table 2. Results of the pairwise comparisons are displayed in the graphs and discussed below. The graphs display arithmetic means ± 1 standard error. Letters in the graphs denote significance of differences between all pairs to facilitate comparisons among areas, years, and seasons on the same graph. Means whose labels do not contain a letter in common differ significantly ($\alpha = 0.05$). All elevations are provided in NGVD '29.

Elevation

In Fringe A, plot elevations ranged from 1.48 to 2.39 ft and averaged 1.90 ± 0.08 ft. Half of the 16 Fringe A plots met the target elevation range of 1.6 – 2.0 ft, with three plots falling below the targeted range and five above. Although half of the Fringe A plots measured in 2006 fell outside the targeted elevations, all fell within the range for the targeted low/mid-marsh habitat (based on USACE planning documents for Kingman Marsh and the Fringe Wetlands and assuming a mean high tide of 2.2 ft NGVD '29). In 2006, elevations at Fringe B plots ranged from 1.76 to 3.24 ft and averaged 2.36 ± 0.06 ft, significantly higher than Fringe A. Although only 22 % of Fringe B plots met the targeted elevation range, with the remainder coming in above-target, 62 % of Fringe B plots fell within the range for the targeted low/mid-marsh habitat.

By way of comparison, a year after construction, elevations at Kingman Marsh ranged from 1.20 to 2.47 and averaged 1.80 ± 0.03 ft. Three years later, following extensive Canada goose herbivory, elevations ranged from 0.61 to 2.42 ft and averaged 1.66 ± 0.04 ft. Elevations for Kenilworth Marsh were measured in 2001, 8 years after construction, when values at Mass Fill 1 ranged from 2.14 – 3.18 ft and averaged 2.81 ± 0.05 ft and values at Mass Fill 2 ranged from 1.65 – 2.58 ft and averaged 2.13 ± 0.05 ft.

Figure 2 presents data limited to plots measured in both 2006 and 2007. The graph shows that elevations in the plots measured in both years increased from 2006 to 2007, although the differences between years were significant only for Fringe A, where elevations averaged 1.90 ± 0.08 ft in 2006 compared to 2.10 ± 0.04 ft in 2007. The data for Fringe B show that elevations in the plots measured twice remained statistically equivalent. The lack of statistical significance between 2006 elevations for Fringe A and Fringe B in this graph reflects the fact that it does not include the highest elevation plots, because these were not measured in both years. Over the long term, increase in elevation through sediment deposition would be anticipated as a result of substantial vegetation and high levels of sediment carried in the Anacostia. The short-term elevation gain was not necessarily predictable because consolidation and compression of the recently-placed sediments often compensate for sediment deposition (Hammerschlag et al. 2006).

In a freshwater tidal wetland, the significant differences in elevation observed between Fringe A and Fringe B in 2006 would be expected to correspond with differences in the depth and duration of tidal inundation experienced by the two areas, which in turn would be expected to translate into differences in total vegetative cover and species richness (Leck 2003), as well as the composition of species dominating cover in the two areas (Simpson et al. 1983, Odum et al. 1984, Neff 2002). Problems with the exotic invasive species *Phragmites australis* would be anticipated at Fringe B, where many plots measured in above 2.1 ft, the lowest elevation at which *Phragmites* was found at Kingman (Neff 2002).

Species List

One hundred and forty-one plant species have been observed in the Fringe Wetlands over the course of the five-year monitoring study, which is comparable to the two preceding Anacostia wetland restorations, Kenilworth Marsh and Kingman Marsh, where 137 species and 151 species were observed, respectively (Stauss 1995, Hammerschlag et al. 2006). This number also compares favorably to the 92 species observed from field vegetation samples in a 32.3-ha tidal freshwater wetland created on the Delaware River in New Jersey (Leck 2003) but is higher than the 50 to 60 species quoted by Odum for natural freshwater tidal marshes (Odum et al. 1984). These findings suggest that, at least for tidal freshwater marsh restorations, many native species will be able to colonize the new substrate and supplement species richness and diversity. Plantings can focus on a few dominant species that are desired, but may not be present in the seedbank or in propagules dispersed into the marsh restoration by tidal water, wind, or animals (Neff and Baldwin 2005). This is in contrast to recommendations for planting strategies for tidal salt marshes, which indicate that plantings should include natural levels of plant diversity rather than relying upon volunteers (Sullivan 2001).

A Fringe Wetlands species list that includes scientific and common names, species acronyms, taxonomic families, years in which species were observed, US Fish and Wildlife Service (USFWS) Wetland Indicator Status, origin, life form, and duration is provided in the Appendix. The following summary is designed to highlight the most relevant aspects of the species list.

Years in which species were observed provide some insights into species turnover over the course of the project. Forty-three percent of plant species were observed in at least four years of the five-year study, suggesting that they were well adapted to the conditions they encountered. At the other extreme, 12 % of plant species were observed in only the first one or two years of the study. Many of the early transients were species such as *Artemisia annua* (sweet sagewort) and *Digitaria sanguinalis* (hairy crabgrass) which are more typically found in upland settings. Others, such as *Cyperus erythrorhizos* (redroot flatsedge), which would typically be found in a wetland setting, appear to be pioneer species capable of colonizing a freshly disturbed site, but incapable of sustaining dominance over time as more competitive species move in. In the fifth year of the project, 95 species were observed in the Fringe Wetlands.

USFWS Wetland Indicator Status is a useful tool in determining whether the species observed in the wetland restoration project are species one would typically expect to find in wetland settings. Of the 141 species observed at the Fringe Wetlands over the duration of the project, 64 % are characterized as Facultative Wet (FACW) or wetter, meaning that they are found in wetland settings in at least 67% of the time. A subset of the FACW or wetter group consists of Obligate (OBL) Wetland plants, which are found in wetlands >99% of the time. Thirty-eight percent of the 141 species observed in the Fringe Wetlands meet the more stringent OBL criterion. Thirteen percent of the 141 species are classified as Facultative Upland (FACU) or drier (found in uplands > 67% of the time). Sixteen percent of the species are more facultative in nature, with classifications falling between FACW and FACU. The remaining 3 % of species/taxa were not classified. For purposes of comparison, species FACW or wetter constituted 44 % to 60 % of species observed at two restored and two created non-tidal freshwater wetlands in Ohio (Thompson et al. 2007), and approximately 64 % of taxa observed in field vegetation samples at a freshwater tidal wetland created on the Delaware River in New Jersey (Leck 2003). It is worth noting that in 2007, the fifth year of the Fringe Wetlands project, species FACW or wetter constituted 78 % of the 95 species observed in the wetlands and provided 98 % of the cover in the quantitative vegetation plots.

Also of significant interest from the standpoint of wetland restoration success is the topic of species origin. Are the species observed in the wetland native or introduced in origin? From the standpoint of species numbers, 76% of the observed species are classified as native in origin, with 20% classified as introduced (and 4% with no classification). This is comparable to the numbers observed in the Ohio study, where native species accounted for 75 % to 83 % of all species observed (Thompson et al. 1984). In the Delaware River study (Leck 2003), 88 % of field vegetation species were classified as native.

The dominant life form present at the site is the forb/herb group which accounts for 55% of observed species. This category is characterized by non-woody broad-leaved plants such as *Peltandra virginica* (green arrow arum), *Sagittaria latifolia* (broadleaf arrowhead), and

Lythrum salicaria (purple loosestrife). The second most common category in terms of numbers of species observed is the graminoid category, which contains important grasses such as *Leersia oryzoides* (rice cutgrass), *Zizania aquatica* (annual wildrice) and *Phragmites australis*, as well as sedges such as *Schoenoplectus tabernaemontani* and rushes such as *Juncus effusus* (common rush). The remaining species are categorized as tree (6%), vine (3.5%) or shrub (1%). This breakdown of species by life form is consistent with that found in a freshwater tidal marsh.

Eighty-six percent of observed species are characterized as perennial, with only 11% categorized as annual (3.5% were unclassified). In contrast, Leck (2003) found that annuals accounted for 38 % of species observed in cover samples at a created tidal freshwater wetland on the Delaware River, compared to 62 % biennials, perennials and woody species (grouped here as "perennials"). She found similar proportions in corresponding seedbank samples. Closer examination of these results reveals that much of the difference relates to the same species being classified differently based on the different sources used and whether species classified as annual/perennial are lumped with annuals or perennials. In some cases this may also reflect species behaving as annuals in New Jersey and perennials further south in Washington DC.

Total Vegetative Cover

Total vegetative cover represents the sum of the cover values for individual species. Although cover for an individual species may not exceed 100%, total vegetative cover may exceed 100% in cases where different species provide overlapping cover.

Total vegetative cover increased significantly since the first year of the project and remains high five years post-reconstruction (Figure 3, Photograph 6). Total vegetative cover was lowest soon after the initial site establishment and planting in the fall of 2003, when it averaged 22.8 ± 5.8% for Fringe A and 58.9 ± 5.9 % for Fringe B. By comparison, cover values from the summer of 2007 averaged 149.1 ± 6.8 % for Fringe A and 137.4 ± 4.0 % for Fringe B in the project's fifth year.

Total vegetative cover has exhibited a significant seasonal component. In the years in which both summer and fall data were collected, summer values were significantly greater than fall values when averaged across areas, reflecting summer peaks exhibited by three important dominant species, *Peltandra virginica*, *Sagittaria latifolia*, and *Zizania aquatica*. When Fringe A and B are considered separately, significance of the differences between summer and fall means varied. In 2007, summer and fall means differed significantly for both Fringe A and Fringe B, when Fringe A averaged 149.1 ± 6.8 % cover in the summer and 109.5 ± 13.8 % in the fall, and Fringe B averaged 137.4 ± 4.0% in the summer and 102.6 ± 7.8 % in the fall.

Although Fringe A and B acted differently with respect to total vegetative cover during the first two years of the project, significant differences between them had disappeared by the third year of the project.

Figure 4 provides a comparison between total vegetative cover at the Fringe Wetlands and at Kenilworth and Kingman, the two prior Anacostia wetland restorations. Data are also included for Dueling Creek, a nearby reference wetland on the Anacostia, which was monitored during the Kingman project. The graph is based on fall data, since this provides the most complete data set. Statistical comparisons were not performed on these data due to methodological differences among the different projects (e.g., sampling at Kenilworth and Kingman used belt transects consisting of contiguous 1m by 5m sectors, whereas sampling at the Fringe Wetlands used independent 1m by 2m plots).

Although the data sets were not compared statistically, a number of valuable conclusions can be drawn from Figure 4. First, it is clear that despite relatively low total plant cover values in the first year of the Fringe Wetlands project, total plant cover after 5 years was comparable to the other sites. Second, total vegetative cover at Kingman Marsh was quite high during the first year of the Kingman project (probably reflecting a comparatively earlier planting time (May/June for Kingman compared to August for the Fringe Wetlands). Third, plant cover in the transects at Kingman had not recovered from the effects of goose herbivory by Year 5. Although portions of Kingman were refenced and replanted by USACE in 2002 (Hammerschlag et al. 2006), much of the site (including most of the area covered by the transects) remains unfenced and accessible to goose herbivory. Fourth, total vegetative cover at Kenilworth Marsh remained high five years into the project. Finally, total vegetative cover at the Fringe Wetlands in Year 5 was comparable to both the 5-year old Kenilworth Marsh restoration and Dueling Creek, a nearby Anacostia reference wetland.

Species Richness

Species richness can be thought of in two ways. One is the overall number of species observed at the site during quantitative sampling and walk throughs. As mentioned previously, 141 plant species have been observed in the Fringe Wetlands over the course of the five-year monitoring study, which is comparable to the two preceding Anacostia wetland restorations, Kenilworth and Kingman, where 137 species and 151 species were observed, respectively (Stauss 1995, Hammerschlag et al. 2006). This number also compares favorably to the 92 species observed in field vegetation samples at a 32.3-ha tidal freshwater wetland created on the Delaware River (Leck 2003) but is higher than the 50 to 60 species quoted by Odum for natural freshwater tidal marshes (Odum et al. 1984). These findings suggest that, at least for tidal freshwater marsh restorations, many native species will be able to colonize the new substrate and supplement species richness and diversity. Plantings can focus on a few dominant species that are desired, but may not be present in the seedbank or in propagules dispersed into the marsh restoration by tidal water, wind, or animals (Neff and Baldwin 2005). This is in contrast to recommendations for planting strategies for tidal salt marshes, which indicate that plantings should include natural levels of plant diversity rather than relying upon volunteers (Sullivan 2001).

Species richness can also be considered from the standpoint of number of species observed in each 2 m^2 plot, which permits statistical analysis through repeated measures ANOVA. As shown in Figure 5, species richness increased significantly from 2003 to 2004, with an average of 4.1 ± 0.5 species observed per 2- m^2 plot in Fringe A in 2003 compared to 9.8 ± 1.2 in 2004, and 5.6 ± 0.5 species observed on average in Fringe B in 2003 compared to 8.9 ±

1.1 species in 2004. Species richness values for 2007 do not differ statistically from those observed in 2004 (summer arithmetic means of 7.9 ± 0.8 species per plot for Fringe A and 8.8 ± 0.8 species for Fringe B). Species richness did not exhibit the seasonal aspect observed for total vegetative cover, indicating that for the most part the species are present during both the summer and fall sampling events, although the cover contributed by those species may vary dramatically with the season. Differences between Fringe A and Fringe B within sampling events were not statistically significant.

Diversity

Diversity is a concept that incorporates both richness (i.e., how many species are present) and evenness (i.e., how evenly is the abundance measure, in this case cover, distributed among the species). We have chosen to address this topic with a commonly used measure of diversity, the Shannon diversity index.

Figure 6 displays the arithmetic means for the Shannon diversity index by area and sampling event. As indicated by the statistical labels, Fringe A and Fringe B do not differ significantly with respect to diversity. Averaging across areas and seasons, the pairwise comparisons indicate that diversity was significantly greater in 2006 and 2007, when it averaged 1.36 ± 0.05 and 1.49 ± 0.05, respectively, than in 2003, when it averaged 1.17 ± 0.08.

By way of local comparisons, diversity at Kingman Areas 1 and 2 averaged 1.52 ± 0.13 and 1.93 ± 0.06, respectively, in the first year of the project, but dropped to 0.45 ± 0.09 and 0.37 ± 0.12, respectively by the fifth year following extensive Canada Goose herbivory (Hammerschlag et al. 2006). Dueling Creek, the Anacostia reference wetland monitored during that study, exhibited a diversity of 1.57 ± 0.04 and 1.36 ± 0.07 in those same years. Diversity at a natural reference marsh located near Jug Bay on the Patuxent also exhibited similar diversity values in year one of that study (1.42 ± 0.12), although by the fifth year its diversity had dropped to 1.24 ± 0.12 as a result of increased inundation due to beaver activity.

Kent and Coker (1992) indicate that values for the Shannon diversity index typically range from 1.5 to 3.5, but their two example data sets actually come in at 1.36 and 1.04. In a comparison of non-tidal freshwater restored and created wetlands in Ohio, Shannon diversity index values averaged 0.90 ± 0.11 and 0.98 ± 0.22 for the restored wetlands, compared to 1.89 ± 0.14 and 0.98 ± 0.23 for two created wetlands (Thompson et al. 2007).

Evenness

Using Shannon's index of evenness it is possible to tease a separate measure of evenness out of the broader diversity index which incorporates both richness and evenness. Figure 7 displays arithmetic means for the evenness index by area and seasonal sampling event. None of the differences between areas are significant. Averaging across areas and seasons(years) does lead to significant differences among years, however (Table 1), with a significant drop in evenness from 2003, when evenness averaged 0.80 ± 0.02, to 2004, when evenness averaged 0.63 ± 0.03. Evenness remained at a lower level until 2007, when averages returned to first-year levels (0.74 ± 0.02). This pattern appears to reflect the fact that in the period from 2004 through the summer of 2006, *Sagittaria latifolia* contributed relatively large amounts of cover. By 2007, cover was distributed more evenly among the dominant species as the population of *Sagittaria* declined.

Dominant Species

Figure 8 is designed to provide a non-statistical overview of species meeting the criterion for dominant species (seasonal mean + 1 SE ≥ 5 %) in each area and how that changed over the five years of monitoring. Figures 9 and 10 provide similar graphs for Years 1 and 5 of the Kenilworth and Kingman restorations, as well as for Dueling Creek, a reference wetland on the Anacostia. Figure 11 provides results of the repeated measures analysis performed on each of the dominant species at the Fringe Wetlands to demonstrate how their contributions to cover have changed statically over time.

<u>Dominant Species Grouped by Area and Year</u>

Four species met the 5 % cover contribution threshold for dominant species at the Fringe Wetlands in 2003, the first year of the project: *Ludwigia palustris* (marsh seedbox), *Peltandra virginica*, *Sagittaria latifolia*, and *Schoenoplectus tabernaemontani* (Figure 8). At Fringe A, *Ludwigia palustris* and *Schoenoplectus tabernaemontani* were the only species to meet the criterion in 2003 providing on average 10.2 ± 4.9 % and 4.2 ± 1.0 % cover, respectively (Figure 8a). At Fringe B, where the elevations turned out slightly higher, all four species met the dominance criterion in 2003, with *Schoenoplectus tabernaemontani* providing the greatest cover at 26.8 ± 4.0 % (Figure 8b). Of these four species, all but *Ludwigia palustris* were planted.

By 2004, the first full growing season of the project, the number of dominant species at Fringe A rose from two to eleven (Figure 8a), with six of those species also meeting the criterion at Fringe B (Figure 8b). In 2004 the 2003 dominants were joined by volunteer species *Bidens connata* (purplestem beggarticks), *Cyperus erythrorhizos*, *Juncus effusus*, *Leersia oryzoides*, *Ludwigia peploides*, *Typha latifolia* (broadleaf cattail), and the newly planted *Zizania aquatica* (thanks to the efforts of the Anacostia Watershed Society).

Numbers of dominants have remained high in the intervening years, with minor reshuffling of species composition. By 2005, *Bidens connata* and *Cyperus erythrorhizos* had decreased in cover and were no longer dominant. By 2006, *Ludwigia palustris* and *Schoenoplectus tabernaemontani* had also dropped off the dominants list at both areas, while *Bidens laevis* and *Impatiens capensis* joined the list at both areas. In 2007, the fifth year of the project, nine species met the criterion of dominant species at Fringe A: *Bidens laevis*, *Impatiens capensis*, *Juncus effusus*, *Leersia oryzoides*, *Lycopus americanus* (American water horehound), *Peltandra virginica*, *Sagittaria latifolia*, *Schoenoplectus tabernaemontani*, *Typha latifolia*, and *Zizania aquatica*. All of them except *Lycopus americanus* and *Typha latifolia* also met the criterion for dominant species in Fringe B.

In order to provide context for the Fringe Wetlands results, we also looked at the dominant species data for the two prior Anacostia wetland restorations, Kenilworth and Kingman, as well as data for Dueling Creek, the nearby Anacostia reference wetland. Data for Kenilworth

Marsh, reconstructed in 1993, indicate that five species/genera met the dominant species criterion at Kenilworth Mass Fill 1 in its first year and six met the criterion at Kenilworth Mass Fill 2 (Figure 9). Of note at Kenilworth Mass Fill 1 was the major role played by *Leersia oryzoides*, which provided 77.2 ± 13.1 % cover by the fall of 2003. Year 5 data show the same numbers of dominant species at each area, although the composition of those lists changed over time. Of the eight species meeting the dominant species criterion at either or both areas, six overlapped with the Year 5 dominant species for the Fringe Wetlands: *Impatiens capensis*, *Leersia oryzoides*, *Peltandra virginica*, *Sagittaria latifolia*, *Typha* spp., and *Zizania aquatica*. It is also worth noting that *Phragmites australis*, which became an invasive problem at both areas some years later, did not meet the criterion for dominant species at either area five years into the project.

Kingman Marsh was reconstructed in 2000. Seven species met the criterion for dominant species in that year at Kingman Area 1, and eight species met the criterion at Area 2 (Figure 10). Of the nine species meeting the criterion at either or both of the areas, six have also been observed as dominants at the Fringe Wetlands: *Cyperus erythrorhizos*, *Leersia oryzoides*, *Ludwigia palustris*, *Sagittaria latifolia*, *Schoenoplectus tabernaemontani*, and *Typha* spp. In the spring of 2001, after an extremely productive first growing season and based on previous experience at Kenilworth Marsh, the decision was made to remove the goose fencing at Kingman. The intense herbivory by resident Canada geese that followed decimated the vegetation at Kingman, as previously illustrated in Figure 4. Although some portions of the site were refenced and replanted by USACE in 2002, much of the site (including most of the area in the transects) was not refenced and replanted, and did not recover from the effects of herbivory. This is reflected in the dominants species data by the fact that the number of dominants species at Kingman Area 1 dropped from seven in 2000 to three in 2004, and similarly from eight at Kingman Area 2 in 2000 to two in 2004. Of the four remaining species meeting the criterion for dominant species in either or both of the areas in 2004, two are exotic invasives, *Lythrum salicaria* and *Phragmites australis* which are not palatable to geese.

Dueling Creek, the Anacostia reference wetland, was included in the areas monitored during the Kingman project. Data from Years 1 and 5 of that project are presented here for comparison. Ten species met the criterion for dominants at Dueling Creek in 2000 (Figure 10). All but one of the ten (*Lythrum salicaria*) are classified as natives. All ten are found at the Fringe Wetlands, although only four have been recorded there at levels constituting dominant species (*Impatiens capensis*, *Leersia oryzoides*, *Peltandra virginica*, and *Polygonum punctatum*, dotted smartweed). In Year 5, Dueling Creek had only six species that met the dominant species criterion, with five species having fallen below the dominant species threshold and one species/genus, *Typha* spp., having surpassed it. The point to be noted here is that even relatively natural reference wetlands such as Dueling Creek can still be dynamic systems where species richness and evenness fluctuate over time.

In summary, nine species met our criterion for dominant species in 2007, Year 5 of the Fringe Wetlands project, which is similar to values observed in the preceding Anacostia wetland restorations, as well as a relatively natural Anacostia reference wetland. Of the nine dominant species, four were planted, seven are obligate wetland plants, and all are native.

Individual Dominants

Figure 8 was designed to provide an overall picture of the dominants present at each area of the Fringe Wetlands in each year. Figure 11 graphs the dominant species individually to show how the amount of cover contributed by each of those species has changed at each area over time. The discussion will focus on common patterns exhibited among groups of species.

Four species met the criterion for dominant species in the earlier years and then declined to sub-dominant levels: *Schoenoplectus tabernaemontani* (one of the seven planted species), *Bidens connata*, *Cyperus erythrorhizos*, and *Ludwigia palustris*. Each of these species occurred at higher levels in Fringe A than in Fringe B (although the differences were not always statistically significant). In the case of the volunteers, *Cyperus erythrorhizos* and *Ludwigia palustris*, this probably reflects their ability as pioneer species to quickly colonize open ground, which was more common at Fringe A in 2003 and the early part of 2004 than at Fringe B. *Schoenoplectus tabernaemontani*, which had proven itself less palatable to Canada geese at the previous wetland restoration at Kingman, constituted 30 % of the plants put in at the Fringe Wetlands in 2003. The decline of *Schoenoplectus tabernaemontani* at the Fringe Wetlands brings into question whether it should constitute a more minor component of planting schemes for future wetland restoration work on the Anacostia. Another year of monitoring in 2008 at the new Heritage Island Wetlands, where it was also planted, should help to clarify whether its performance at the Fringe Wetlands was typical or an anomaly. Even if *Schoenoplectus tabernaemontani* does not persist at dominant levels it may be desirable to retain this species on future planting lists for its ability to provide short-term stability as volunteer species increase to provide a larger role in long-term stability.

Two species peaked in 2005 and/or 2006 and have since exhibited declines. One of these, *Sagittaria latifolia*, constituted 5 % of the initial wetland plantings. Cover for *Sagittaria latifolia* peaked at 45.2 ± 3.5 % in 2005, the greatest annual average for any species observed at the Fringe Wetlands, compared to 10.7 ± 1.7 % in 2007. The cause of this decline in *Sagittaria latifolia* cover is unclear. *Typha latifolia* has exhibited a less dramatic decline at Fringe A in 2007.

A group of five species have seen significant increases in cover in 2006 and/or 2007. These consist of the planted species, *Peltandra virginica* and *Zizania aquatica*, and the volunteer species, *Bidens laevis*, *Impatiens capensis*, and *Lycopus americanus*. *Peltandra virginica* accounted for 45 % of the individuals planted as plugs. *Zizania aquatica* was planted as seed by the Anacostia Watershed Society in 2004.

Four species exhibited a pronounced seasonal component. Three of them, *Peltandra virginica*, *Sagittaria latifolia*, and *Zizania aquatica*, have shown a statistically significant decrease from summer to fall in at least some years, reflected in lower total vegetative cover in the fall compared to the summer sampling events. *Bidens laevis* has exhibited higher cover in the fall than in the summer, although these differences were not statistically significant. Seasonal succession in freshwater tidal wetlands has been noted previously (Whigham et al. 1978, Odum et al. 1984).

Only four of the dominant species have shown significant differences between Fringe A and Fringe B. *Bidens connata*, *Schoenoplectus tabernaemontani*, and *Typha latifolia* have been found at greater levels at Fringe A than at Fringe B, although the first two species only met the criterion for dominant species during the first one or two years. *Bidens laevis* exhibited, on average, significantly more cover at Fringe B than at Fringe A, although data from fall 2007 suggest that the two areas may be converging in that respect.

The changing patterns of dominant species observed at the Fringe Wetlands agree with Leck (2003) who studied a created tidal freshwater wetland on the Delaware River and found that individual species behaved uniquely regarding colonization time, duration and decline in both the seed bank and vegetation.

Planted and Volunteer Species

Cover contributed by the seven planted species is graphed in Figure 12a; cover contributed by volunteer species is graphed in Figure 12b. It should be noted that cover by planted species may include cover by individuals derived from the seedbank present in the dredge sediments used during construction or propagules brought into the system through tidal water dispersal or wind and animal dispersal (Neff and Baldwin 2005), as well as individuals that were planted or derived from individuals that were planted.

Cover contributed by planted species appears to have peaked in 2005, when it averaged 74.8 ± 6.3 % for Fringe A and 71.5 ± 4.4 % for Fringe B, followed by a statistically significant decline in 2007, when it averaged 43.9 ± 6.9 % for Fringe A and 42.6 ± 4.7 % for Fringe B. The 2005 peak and post-2005 decline appear to have been largely driven by *Sagittaria latifolia* (see the section on dominant species). Given that *Sagittaria latifolia* accounted for only 5 % of the initial plantings at the Fringe Wetlands and that exclosures at Kingman provided 25 to 45 % cover from unplanted *Sagittaria latifolia* (Hammerschlag et al. 2006, May 2007), *Sagittaria latifolia* measured at the Fringe Wetlands and included in the planted species totals may have actually represented a mix of planted and volunteer sources.

The section on dominant species also documents the performance of the four other planted species (*Juncus effusus*, *Peltandra virginica*, *Schoenoplectus tabernaemontani*, and *Zizania aquatica*) that met the criterion for dominant species in at least one sampling event. Of these, *Peltandra virginica* and *Zizania aquatica* have exhibited the most significant and durable influence on planted species cover. Like *Pontedaria cordata*, *Nuphar lutea* constituted 5 % of the initial plantings and did not meet the criterion for dominant species in any of the sampling events. The failure of *Nuphar lutea* to meet the dominant species criterion probably reflects the fact that *Nuphar* was planted in a thin zone around the lower elevation perimeter of the restoration area that received few random plots, as well as the fact that it was planted in relatively low numbers.

Cover by planted species also exhibited a significant season(year) effect, with summer cover exceeding fall cover in the years when both were measured. Based on the data presented in the section on dominant species, this effect appears to have been driven by three dominant species, *Peltandra virginica*, *Sagittaria latifolia*, and *Zizania aquatica*.

Cover by volunteer species (Figure12b) exhibited an early spike at Fringe A in 2004, when it averaged 83.5 ± 12.6 %, followed by a significant decline in 2005, when it averaged 42.2 ± 6.0 % in Fringe A. Based on the data provided in the section on dominant species, this phenomenon was probably driven by a corresponding spike and decline exhibited by *Leersia oryzoides*, supplemented by smaller spikes in *Ludwigia peploides*, *Ludwigia palustris*, and *Cyperus erythrorhizos* in Fringe A. By 2007, volunteer cover at Fringe A had rebounded to 85.4 ± 10.2 %, with Fringe B not significantly behind at 77.4 ± 6.0 %. This significant increase in cover can be largely attributed to the performance of *Impatiens capensis* and *Bidens laevis*, and to a lesser extent, *Lycopus americanus*. Cover by volunteer species did not exhibit the strong seasonal component displayed by planted species.

Results of the multiple comparisons on least square means for planted species and volunteer species indicate that both groups contributed significant amounts of cover except for Fringe A in the fall of 2003, when neither cover by planted species nor cover by volunteer species differed significantly from 0 (overall $\alpha = 0.05$).

In conclusion, both planted and volunteer species have contributed to the cover established in the Fringe Wetlands in the five years since its construction. Cover from planted species peaked in 2005 and has declined significantly since then (although summer averages remain relatively robust at 70.4 ± 9.9 % and 65.9 ± 7.0 % for Fringe A and Fringe B, respectively, in summer 2007). As cover contributed by planted species has gradually declined, cover from volunteer species has gradually increased, showing that the Fringe Wetlands are providing a favorable habitat for the establishment of a wide array of typical wetland species that were either present in the seedbank or were dispersed into the site from tidal water, wind, or animals. Significance of differences between Fringe A and Fringe B with respect to cover contributed by planted and volunteer species was limited to the first two years.

Wetland and Upland Species

One important measure of the success of a wetland restoration is whether the plants occupying the restored habitat are primarily classified as wetland or upland in character. In the species list section it was pointed out that species ranked FACW or wetter constituted 64 % of the species that have been observed at the Fringe Wetlands over the course of the 5-year study, and 78 % of the species observed in 2007. The purpose of this section is to expand the examination from presence/absence data to more ecologically meaningful quantitative cover data. This was done by calculating the cover provided by two groups of plants, those with a USFWS Wetland Indicator Status of Facultative Wet (FACW) or wetter and those with a USFWS Wetland Indicator Status of Facultative Upland (FACU) or drier.

Cover provided by plants FACW or wetter is graphed in Figure 13. Cover by FACW or wetter plants has increased significantly from 2003, when it averaged 43.4 ± 4.8 %. It remained high in 2007 averaging 120.4 ± 4.2 % and representing 98 % of total vegetative cover. The only significant difference between Fringe A and Fringe B during a sampling event occurred in Fall 2004, when Fringe A cover by FACW or wetter plants was significantly greater than Fringe B. Cover by FACW or wetter plants exhibited a significant seasonal component, with summer cover averaging higher than fall cover in all years when both were measured. This reflects a similar seasonal pattern exhibited by three dominant species, *Peltandra virginica*, *Sagittaria latifolia*, and *Zizania aquatica*.

Data for cover by species FACU or drier peaked sharply in 2004 at 1.6 ± 0.5 %; by 2007 it averaged 0.1 ± 0.1 %. Given the paucity of the data and the fact that it did not meet the normality assumptions for an ANOVA even after transformation, no statistical tests were performed on the data for cover by plants FACU or drier.

Cover calculations indicate that beyond the presence/absence information that species ranked FACW or wetter constituted 64 % of the species observed at the Fringe Wetlands over the course of the 5-year study and 78 % of the species observed in 2007 (Year 5), the cover data are much more striking and ecologically meaningful, with 98 % of the cover in 2007 provided by species ranked FACW or wetter. This indicates that the Fringe Wetlands restoration has resulted in habitat supportive of typical wetland species.

Native and Exotic Species

Another indicator for successful wetland restoration is whether it is vegetated mostly by native or introduced species. As mentioned previously, from the presence/absence standpoint, 76 % of the species observed during the 5-year study are classified as natives and 20 % are classified as exotic (4 % were genera and therefore unclassified).

Figure 14 presents graphs of cover contributed by natives (Figure14 a) and exotics (Figure14 b). They are presented at the same scale to allow a more direct comparison. At Fringe A, cover by natives increased significantly from 2003 to 2004, when it leveled off from the statistical standpoint. Natives at Fringe B increased in cover more slowly, increasing significantly from 2004 to 2005 before leveling off. Cover contributed by natives remained high in 2007, averaging 117 ± 4.2 % and representing 95 % of total vegetative cover. Native species cover exhibited a significant seasonal component, with summer cover providing greater cover on average than fall cover measured in the same year.

Cover by exotics (Figure 14b) increased significantly from 2003 to 2004, but still remained relatively low. In 2007, cover by exotics averaged 6.1 ± 1.4 %, representing 5 % of total vegetative cover. Starting in 2005, levels at Fringe B have been greater than at Fringe A, although this difference is not statistically significant. None of the seasonal differences proved statistically significant. None of the exotics met the criterion for dominant species during any of the sampling events.

Although cover at the Fringe Wetlands is dominated by natives rather than exotics five years post-reconstruction, the presence of *Phragmites australis*, *Lythrum salicaria*, and *Murdannia keisak* at sub-dominant levels in the Fringe Wetlands remains a source of concern. In the field, it seems that the random plot placement may be under-representing the populations of *Phragmites* and *Lythrum.* This may have resulted if the spatial scale of the monitoring is different from the spatial scale of the exotic plant invasion. In addition, previous experience at Kenilworth has shown that although *Phragmites australis* did not meet the criterion for a dominant species at Kenilworth during its first five years, the species subsequently increased to problematic dominant levels. Given this history, NPS has, in fact, already sprayed *Phragmites* at the Fringe Wetlands with herbicide for the first time in 2007. Continued monitoring of these three exotic species is recommended, since all of them have the potential to increase to problematic levels.

Annual and Perennial Species

Cover contributed by annuals increased significantly over time at both Fringe A and Fringe B (Figure 15a), averaging 0.4 ± 0.2 % in 2003 compared to 39.8 ± 3.3 % in 2007. The extremely low levels measured in 2003 reflect the fact that *Zizania aquatica*, the only annual species planted, was not seeded in by the Anacostia Watershed Society until 2004. The low cover levels from annuals at the Fringe Wetlands in 2003 probably also reflect a reduction in germination of annuals from the seedbank resulting from the fact that the Fringe Wetlands were constructed relatively late in the growing season, with planting not completed until August. The significant increases observed in 2006 reflect concurrent increases in *Zizania aquatica* and *Impatiens capensis*, the only two annual species still present at dominant levels in 2006 (since *Cyperus erythrorhizos* dropped to sub-dominant levels in 2005). Significant seasonal effects of interest were limited to 2007, when summer cover exceeded fall cover. This drop in annuals in the fall of 2007 appears to reflect a similar seasonal decline in *Zizania aquatica*.

Cover contributed by perennials (Figure 15b) in Fringe A peaked in 2004, followed by a statistically significant decline in 2006 which was sustained in 2007. Fringe B peaked in 2005, followed by a similar significant decline in 2006 sustained in 2007. This pattern appears to have been heavily influenced by the decline in *Sagittaria latifolia* recorded for the same time frame, ameliorated by concurrent increases in cover exhibited by *Bidens laevis*, *Peltandra virginica*, and *Lycopus americanus*. In spite of these declines, perennial cover remained reasonably high in 2007, when it averaged 83.25 ± 4.0 %. Averaging across areas, summer cover was significantly greater than fall cover in both 2006 and 2007. This pattern appears to have been driven by similar patterns exhibited by *Peltandra virginica* and *Sagittaria latifolia*.

Elevation Regressions

Regression analysis was performed for total vegetative cover versus elevation (Figure 16a) and species richness versus elevation (Figure 16b) using vegetation and elevation data collected during 2006. Total vegetative cover increased with increasing elevation at both areas, although the relationship was statistically significant only at Fringe B ($p = 0.0826$ for Fringe A, $p < 0.0001$ for Fringe B). It is worth noting that the positive relationship is not significant at Fringe A because some of the lower elevation plots in Fringe A actually correspond with fairly high values for total vegetative cover provided by two or three strata of vegetation (with *Ludwigia peploides* in some cases providing a prostrate stratum, *Peltandra virginica* with or without *Sagittaria latifolia* providing a middle stratum, and *Zizania aquatica* with or without *Typha latifolia* providing a tall stratum). A positive relationship between total vegetative cover and elevation has been documented previously at the Kingman and Kenilworth Marsh restorations (Hammerschlag et al. 2006).

Species richness also increased significantly with increasing elevation at both areas ($p = 0.0002$ for Fringe A and $p < 0.0001$ for Fringe B). This positive relationship between species richness and elevation has also been previously documented at Kingman and Kenilworth (Hammerschlag et al. 2006). Leck (2003) has documented a complimentary inverse relationship between species richness and inundation in her study of a created tidal freshwater wetland on the Delaware River in New Jersey.

Dominant Species Cover versus Elevation

Cover versus elevation data (both from 2006) are displayed in two ways. Figure 17 provides scatter plots for each dominant species plus three species of special concern, *Phragmites australis*, *Lythrum salicaria* and *Murdannia keisak*. The scatter plots depict data from each plot, including plots where the cover for that species is 0 %, making it possible to see which elevations are unoccupied by individual species. The scatter plots also distinguish between plots in Fringe A and Fringe B. Figure 18 provides a schematic summary of the data designed to show both the entire range of plot elevations where the species was observed in 2006 as well as the range of elevations associated with the plots where 75 % of that species cover is concentrated. Figure 18 does not distinguish between areas. Figure 18 includes key dominants plus the three species of special concern.

The scatter plots in Figure 17 are useful because they make it easier to visualize the fact that although elevations overlap between the two areas, Fringe B is characterized by an upward shift in elevations with respect to Fringe A. The scatter plots also illustrate that species may occupy different elevations at different areas. *Leersia oryzoides*, for example, drops out between 2.2 – 2.3 ft at Fringe B, whereas it appears at comparable cover levels down to 1.9 ft in Fringe A. Many factors including random colonization events could account for these differences. Finally, the scatter plots illustrate that some species such as *Peltandra virginica* appear capable of occupying a broad range of elevations, while other species such as *Zizania aquatica* occupy a narrower range (at least at the Fringe Wetlands during 2006).

The schematic diagram pictured in Figure 18 makes it easier to visualize the range of elevations where the top 75 % of the data is concentrated for each species considered, as well as the absolute range of elevations for the plots in which they were found. The data indicate that some species, such as *Impatiens capensis* and *Typha latifolia* occupy broad elevation ranges with relative cover spread over that whole range, although *Typha latifolia* clearly represents a shift towards lower elevations compared to *Impatiens capensis*. Our data place *Impatiens capensis* in the mid- and high marsh, which agrees with the published literature (Simpson et al. 1983, Odum et al 1984). Unlike the published literature, which places *Typha* sp. (*T.latifolia*, *T. domingensis*, and *T. angustifolia*) in the high marsh (Mitsch and Gosselink 2000), our data place the *Typha latifolia* category (which includes *Typha glauca*, the hybrid with *Typha angustifolia*) in all three marsh zones, low, mid-, and high. *Typha angustifolia* is sometimes quoted as occupying a lower position in the marsh than *Typha latifolia*. In this study *Typha angustifolia* occurred at sub-dominant levels in plots in the mid- and high marsh. Like our study, work done for previous wetland restorations on the Anacostia place *Typha* spp. in the low, mid- and high marshes (Neff 2002).

Three dominant species have zones of concentration extending down to 1.5 ft (low marsh), *Zizania aquatica*, *Typha latifolia* and *Sagittaria latifolia*. Our data place *Zizania aquatica* mostly in the low and mid-marsh. This agrees fairly well with the literature, although Simpson et al. (1983) extend *Zizania aquatica* through the high marsh. *Typha latifolia* has already been discussed. Our data and the literature also place *Sagittaria latifolia* in the low, mid- and high marsh (Simpson et al. 1983, Odum et al. 1984).

Bidens laevis is exhibiting the narrowest zone of concentration extending from 2.3 – 2.5 ft (high marsh), although 25 % of the relative cover is occurring below that in the 1.5 – 2.3 ft range (low and mid-marsh). The literature places *Bidens laevis* in the low, mid- and high marsh.

Two species of concern, *Phragmites australis* and *Lythrum salicaria*, are occupying basically the same elevation range from 2.3 -3.1 ft (mostly high marsh). Although usefulness of the *Phragmites* data is limited by the fact that it was found in only two plots, the data do match the findings of Neff (2002), who showed that no *Phragmites* occurred in plots with elevations below 2.1 ft. Neff's data for *Lythrum salicaria* indicate that the species is capable of occupying elevations down to 1.8 ft at high levels of cover, although to date *Lythrum salicaria* is only found at mostly high marsh elevations (down to 2.3 ft) in the Fringe Wetlands. *Murdania keisak*, the third species of concern, which occurred in only four plots, appears to occupy an elevation niche that overlaps with the Fringe Wetlands ranges for *Phragmites australis* and *Lythrum salicaria* but extends below them into the mid-marsh (down to 1.9 ft).

CONCLUSIONS:

The Fringe Wetlands have been monitored for five growing seasons since their reconstruction in 2003. In this report a number of indicator metrics have been evaluated and compared to results for Kenilworth Marsh and Kingman Marsh, two previous Anacostia tidal freshwater marsh restoration efforts, and Dueling Creek, an Anacostia reference wetland monitored during the Kingman Marsh project. The most important of those evaluations and comparisons are summarized below.

The elevation of the marsh surface in the Fringe Wetlands plots measured in 2006 covered a fairly broad range, with Fringe A elevations ranging from 1.48 to 2.39 ft and averaging 1.90 ± 0.08 ft and Fringe B coming in significantly higher, ranging from 1.76 to 3.24 ft and averaging 2.36 ± 0.06 ft. Based on a mean high tide of 2.2 ft NGVD '29, this translates into Fringe A consisting of low and mid-marsh elevations, and Fringe B consisting of mostly mid- and high marsh elevations. By way of comparison, elevations at Fringe A plots match fairly well with early Kingman Marsh elevations, with the significant exclusion of the lowest group of elevations measured at Kingman. Fringe B plot elevations overlapped with those at Fringe A, but were more similar to those measured at Kenilworth Marsh. All of the Fringe A plots were measured again in 2007, exhibiting a significant increase to a new average of 2.10 ± 0.04 ft. Those Fringe B plots that were measured again in 2007 (which did not include the highest elevation plots) exhibited a smaller non-significant increase in elevation.

Total vegetative cover at the Fringe Wetlands averaged 123.1 ± 4.3 % in 2007, reflecting solid cover that includes overlapping species. Kingman's fifth year average of 26.9 ± 5.0 % provides a striking contrast of what can happen when a wetland restoration effort is decimated by resident Canada goose herbivory. Ninety-eight percent of the total vegetative cover measured at the Fringe Wetlands in 2007 was provided by plants typically found in wetlands; 95 % was provided by native species. Fringe A and Fringe B performed similarly with respect to total vegetative cover, and cover provided by wetland and native species, with significant differences between them limited to the first two years of the project.

One hundred and forty-one plant species have been observed at the Fringe Wetlands, compared to 137 species at Kenilworth Marsh, 151 at Kingman Marsh, 92 at a created tidal freshwater wetland on the Delaware River (Leck 2003), and 50 to 60 species cited as the norm for natural tidal freshwater wetlands (Odum et al. 1984). These findings suggest that, at least for tidal freshwater marsh restorations, many native species will be able to colonize the new substrate and supplement species richness and diversity. Plantings can focus on a few dominant species that are desired, but may not be present in the seedbank or in propagules dispersed into the marsh restoration by tidal water, wind, or animals (Neff and Baldwin 2005). This is in contrast to recommendations for planting strategies for tidal salt marshes, which indicate that plantings should include natural levels of plant diversity rather than relying upon volunteers (Sullivan 2001).

Shannon's diversity index averaged 1.49 ± 0.05 at the Fringe Wetlands in 2007, again providing a striking contrast to the 0.39 ± 0.07 observed at Kingman in its fifth year, and also comparing favorably to the values for Dueling Creek, an Anacostia reference wetland, whose averages ranged from 1.20 ± 0.09 to 1.45 ± 0.06 during the five years it was monitored with Kingman Marsh. Fringe A and Fringe B showed no significant differences with respect to diversity.

In 2007, nine species met the criterion for dominant species at the Fringe Wetlands by providing at least 5 % cover in at least one season. Although Fringe A and Fringe B exhibited significant differences in cover levels by dominant species earlier in the project, by 2007, the two areas did not differ significantly with respect to cover levels for the nine dominant species. Of these nine dominant species, four were planted, all are species typically found in wetlands, and all are native. By contrast, only four species met the criterion for dominant species at Kingman after five years, and two of them were invasive exotics. Numbers of dominant species at Dueling Creek varied by year and ranged from six to ten species. Of the eleven dominants observed at Dueling Creek, all were typical wetland plants and ten of the eleven were natives.

Planted and volunteer species have each made significant contributions to cover at both Fringe A and Fringe B, with significant differences between the two areas limited to the first two years of the project. As cover contributed by planted species has gradually declined, cover from volunteer species has gradually increased, showing that the Fringe Wetlands are providing a favorable habitat for the establishment of a wide array of typical wetland species that were either present in the seedbank or were dispersed into the site from tidal water, wind, or animals. The two planted species that have provided the most significant persistent cover at the Fringe Wetlands are *Peltandra virginica*, planted in 2003, and *Zizania aquatica*, planted as seed in 2004 by the Anacostia Watershed Society. *Sagittaria latifolia*, also planted in 2003, has maintained its status as a dominant species for all five years, but appears to be undergoing a significant decline.

Total vegetative cover and species richness both increased as elevation increased. This was expected based on previous findings at Kingman Marsh (Neff 2002) and elsewhere in the literature (Leck 2003). The positive correlation between total vegetative cover and elevation was not statistically significant at Fringe A, however, reflecting the fact that even the lowest elevation plots at Fringe A have two or three overlapping strata of vegetation.

Three exotic invasive species of concern are present at the Fringe Wetlands, *Phragmites australis*, *Lythrum salicaria*, and *Murdannia keisak*. Elevations at Fringe B are comparable to those measured at Kenilworth Marsh where *Phragmites australis* increased to dominant levels, and mostly above the 2.1 ft elevation threshold noted for this species at Kingman Marsh. Therefore, Fringe B may be vulnerable to future expansion of the *Phragmites australis* which currently exists there at sub-dominant levels. In recognition of this possibility, NPS has already sprayed *Phragmites* in the fall of 2007. *Lythrum salicaria*, another invasive exotic, has also been observed at high marsh elevations (2.3-3.1 ft) mostly at Fringe B. *Murdania keisak*, the third species of concern, which has been observed in only four plots, appears to occupy an elevation niche that overlaps with the Fringe Wetlands ranges for *Phragmites australis* and *Lythrum salicaria* but extends below them into the mid-marsh (down to 1.9 ft). All three of these invasive exotic species should receive continued monitoring at the Fringe Wetlands.

In conclusion, the Fringe Wetlands indicator metrics resemble those measured at an Anacostia reference wetland and the previous Anacostia wetland reconstruction efforts (prior to extensive Canada goose herbivory). Total vegetative cover and species diversity and richness remain high in 2007 and do not differ significantly between Fringe A and Fringe B. Resident Canada goose herbivory has not decimated the vegetation, as at Kingman Marsh. Additional research would be needed to determine if the relatively low levels of Canada Goose herbivory observed at the Fringe Wetlands is due to a more favorable geographical location for the Fringe Wetlands (not surrounded by golf course), existence of the sheet piling, existence of a goose deterrent system of fencing, horizontal stringing, and flagging, or a combination of factors. Three exotic invasive species of concern are present in the Fringe Wetlands, but have remained at sub-dominant levels for the first five years of the project. Control measures have already been initiated for *Phragmites australis*, which is typically found at the mid- to high marsh elevations that predominate at Fringe B. Continued monitoring is recommended for all three of these exotic invasives.

The Fringe Wetlands have done well in the five years they have had to become established, protected by sheet piling, fencing, horizontal stringing, and flagging. Interior fencing has been removed from some of the higher elevation transects in December 2007. Additional fence removal activities are scheduled for April 2008. Removal of the sheet piling is currently under consideration. Given the uncertainty in vegetation response and potential increased erosion and herbivory associated with removal of the sheet piling and fencing, it is our recommendation that monitoring be continued for at least three years after the sheet piling is removed to evaluate the impact of the management actions.

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At PWRC, Jeff Hatfield provided statistical support. We also appreciate the graphic support provided by Kinard Boone for the preparation of the composite aerial base map.

PHOTOGRAPHS

Photograph 1. Anacostia wetland restoration sites and reference wetland in September 2003. Dates reflect year of reconstruction.

Dueling Creek Reference

Kenilworth Marsh Mass Fill 1 1993

Kenilworth Marsh Mass Fill 2 1993

Kingman Marsh Area 1 2000

Fringe B 2003

Kingman Marsh Area 2 2000

Fringe A 2003

Photograph 2. Installation of the sheet piling at the Anacostia River Fringe Wetlands.

Photograph 3. Grading of the sediment at the Anacostia River Fringe Wetlands.

Photograph 4. Historical photograph of the Anacostia showing extensive wetlands and the excavation of the northern end of Kingman Lake north of the Benning Road bridge in July 1929. Photograph courtesy of the US National Arboretum.

Photograph 5. Goose deterrent system of fencing, horizontal stringing, and flagging at the north end of Anacostia River Fringe B in August 2003 with the Benning Road bridge and metro in the background.

Photograph 6. The same area with complete cover in June 2007.

Photograph 7. Young *Zizania aquatica*, annual wildrice, in June 2007 at Anacostia River Fringe A.

Photograph 8. *Sagittaria latifolia*, broadleaf arrowhead, in 2003 at Anacostia River Fringe B. Photo courtesy of DDOE.

TABLES

Table 1. Anacostia River Fringe Wetlands planting list for species planted in 2003. *Zizania aquatica*, not included on this list, was planted as seed by the Anacostia Watershed Society in 2004.

Species	**Common Name**	**# Planted**	**% Planted**
Peltandra virginica	green arrow arum	158,540	45
Schoenoplectus tabernaemontani	softstem bulrush	105,680	30
Juncus effusus	common rush	35,220	10
Nuphar lutea	yellow pond-lily	17,610	5
Pontedaria cordata	pickerelweed	17,610	5
Sagittaria latifolia	broadleaf arrowhead	17,610	5
	Total	352,270	

Table 2. Summary statistics (F-values and *P*-values) from the repeated measures analysis of variance (ANOVA) for each variable at the Anacostia River Fringe Wetlands. See text for descriptions of the variables and for details concerning the ANOVA models.

	Fixed Effects Terms in ANOVA Model									
	Area[1]		Year[2]		Area x Year		Season(Year)[3]		Area x Season(Year)	
Variable	**F**	***P***	**F**	***P***	**F**	***P***	**F**	***P***	**F**	***P***
Elevation- all plots[4]	18.29	<0.0001	10.48	0.0026	13.63	0.0007				
Elevation- limited plots[4]	3.96	0.0597	14.68	0.001	3.82	0.0641				
Total Vegetative Cover	0.46	0.5008	71.75	<0.0001	15.85	<0.0001	15.03	<0.0001	0.16	0.9202
Species Richness[5]	0.03	0.8544	24.44	<0.0001	4.4	0.0045	0.72	0.5442	2.9	0.045
Shannon Diversity Index	0.05	0.8208	7.84	<0.0001	1.55	0.1886	0.83	0.4789	2.15	0.094
Shannon Evenness Index	3.81	0.0568	6.85	<0.0001	0.33	0.8603	0.61	0.6102	1.41	0.2397
Cover by:										
Planted Species	0.47	0.4972	33.74	<0.0001	5.88	0.0007	47.6	<0.0001	1.02	0.3908
Volunteer Species	0.63	0.4296	37.97	<0.0001	15.31	<0.0001	12.89	<0.0001	0.42	0.7374
Wetland Species	2.35	0.1323	72.93	<0.0001	15.63	<0.0001	12.23	<0.0001	0.39	0.7632
Native Species	1.43	0.2383	53.74	<0.0001	15.25	<0.0001	13.28	<0.0001	0.29	0.8352
Exotic Species[5]	1.07	0.3072	6.44	0.0004	1.61	0.1886	1.68	0.1846	1.72	0.1776
Annual Species[5]	0.14	0.7095	123.39	<0.0001	5.53	0.0011	9.52	<0.0001	1.25	0.3037
Perennial Species	0.36	0.5487	27.71	<0.0001	13.15	<0.0001	16.89	<0.0001	0.93	0.4321

Continued on next page…

[1] Two areas: Fringe A and Fringe B.
[2] Five years: 2003, 2004, 2005, 2006, 2007.
[3] Two seasons were analyzed: summer (mid-late July) and fall (mostly mid-September). No summer data were collected in 2003 (planting not completed until August) or 2004.
[4] Two separate elevation analyses were conducted, one on all data collected, the other on just those plots measured in both 2006 and 2007.
[5] Natural log transformation was used to improve normality prior to analysis.

Table 2 (Cont.). Summary statistics (F-values and *P*-values) from the repeated measures analysis of variance (ANOVA) for each variable at the Anacostia River Fringe Wetlands. See text for descriptions of the variables and for details concerning the ANOVA models.

	Fixed Effects Terms in ANOVA Model									
	Area[1]		**Year[2]**		**Area x Year**		**Season(Year)[3]**		**Area x Season(Year)**	
Variable	**F**	***P***	**F**	***P***	**F**	***P***	**F**	***P***	**F**	***P***
Cover by:										
Bidens connata[5]	5.68	0.0367	13.96	<0.0001	2.16	0.0727	0.96	0.4124	1.09	0.3525
Bidens laevis[5]	7.81	0.0073	26.82	<0.0001	1.09	0.36	3.82	0.0102	0.72	0.5413
Impatiens capensis[5]	0.3	0.6	34.78	<0.0001	1.04	0.385	0.29	0.8331	0.02	0.9944
Juncus effusus[5]	0.12	0.7388	1.66	0.1586	0.09	0.9867	0.09	0.9662	0.11	0.9528
Leersia oryzoides[5]	1.87	0.2222	11.9	<0.0001	1.58	0.1793	0.18	0.9061	0.14	0.9345
Ludwigia palustris[5]	0.99	0.3494	20.37	<0.0001	4.99	0.0006	0.01	0.9984	0.02	0.995
Lycopus americanus[5]	1.66	0.2434	5.43	0.0003	0.66	0.6216	0.36	0.7828	0.22	0.8835
Peltandra virginica[5]	4.46	0.081	9.58	<0.0001	3.32	0.0108	30.25	<0.0001	0.91	0.435
Polygonum punctatum[5]	1.67	0.2458	11.27	<0.0001	2.83	0.0247	8.75	<0.0001	2.8	0.0396
Sagittaria latifolia[5]	0.09	0.7788	41.03	<0.0001	3.34	0.0105	9.24	<0.0001	0.0665	0.9776
S.tabernaemontani[5]	21.15	0.0014	52.08	<0.0001	9.27	<0.0001	16.43	<0.0001	1.91	0.1273
Typha latifolia[5]	2.83	0.1425	23.48	<0.0001	8.16	<0.0001	0.43	0.7293	0.33	0.8043
Zizania aquatica[5]	0.02	0.8963	10.42	<0.0001	0.43	0.7856	7.48	<0.0001	0.29	0.8291

[1]Two areas: Fringe A and Fringe B.
[2]Five years: 2003, 2004, 2005, 2006, 2007.
[3]Two seasons were analyzed: summer (mid-late July) and fall (mostly mid-September). No summer data were collected in 2003 (planting not completed until August) or 2004.
[4]Two separate elevation analyses were conducted, one on all data collected, the other on just those plots measured in both 2006 and 2007.
[5]Natural log transformation was used to improve normality prior to analysis.

FIGURES

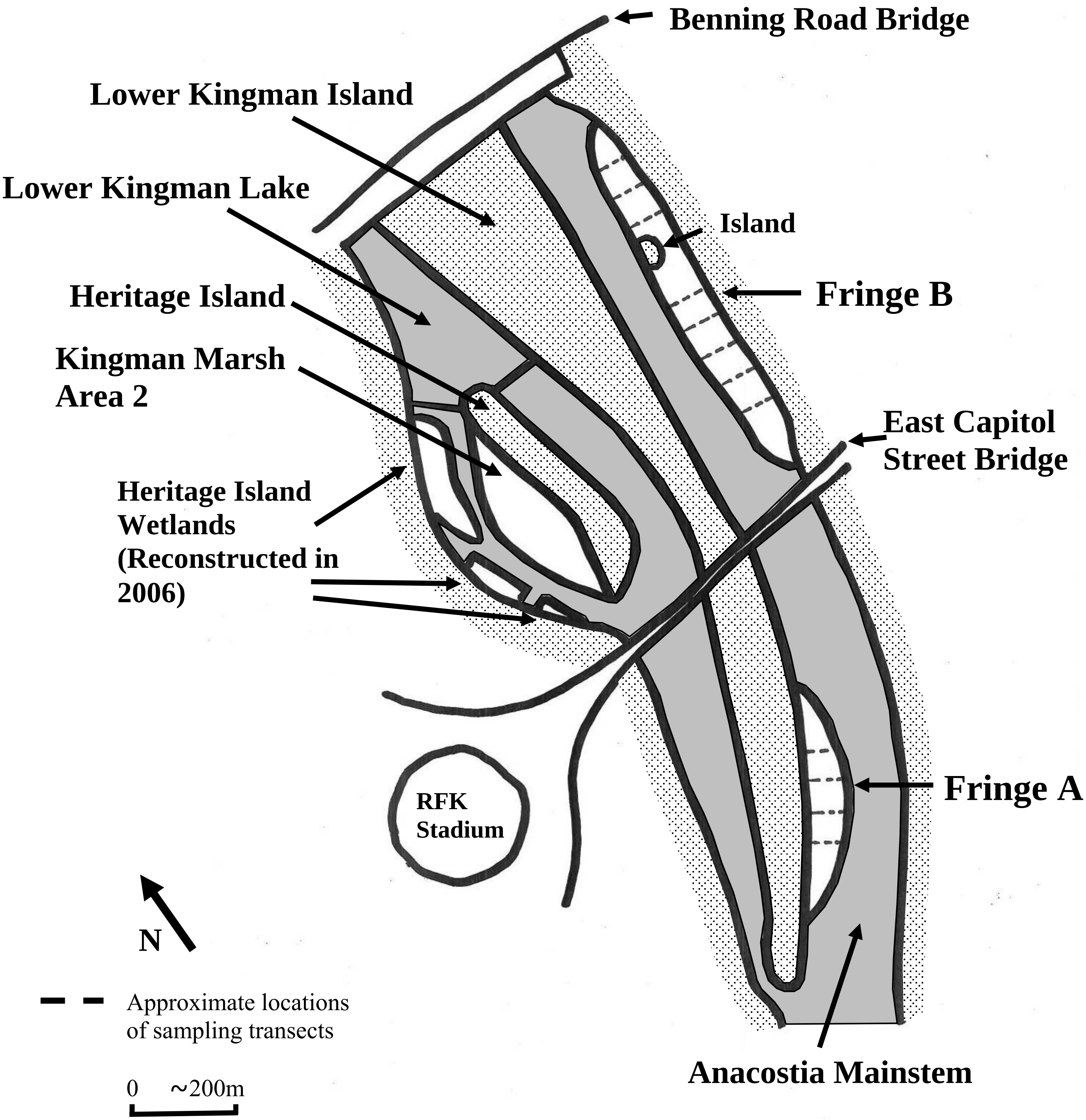


Figure 1. Schematic diagram of Fringe A and Fringe B at the Anacostia River Fringe Wetlands Restoration Project.

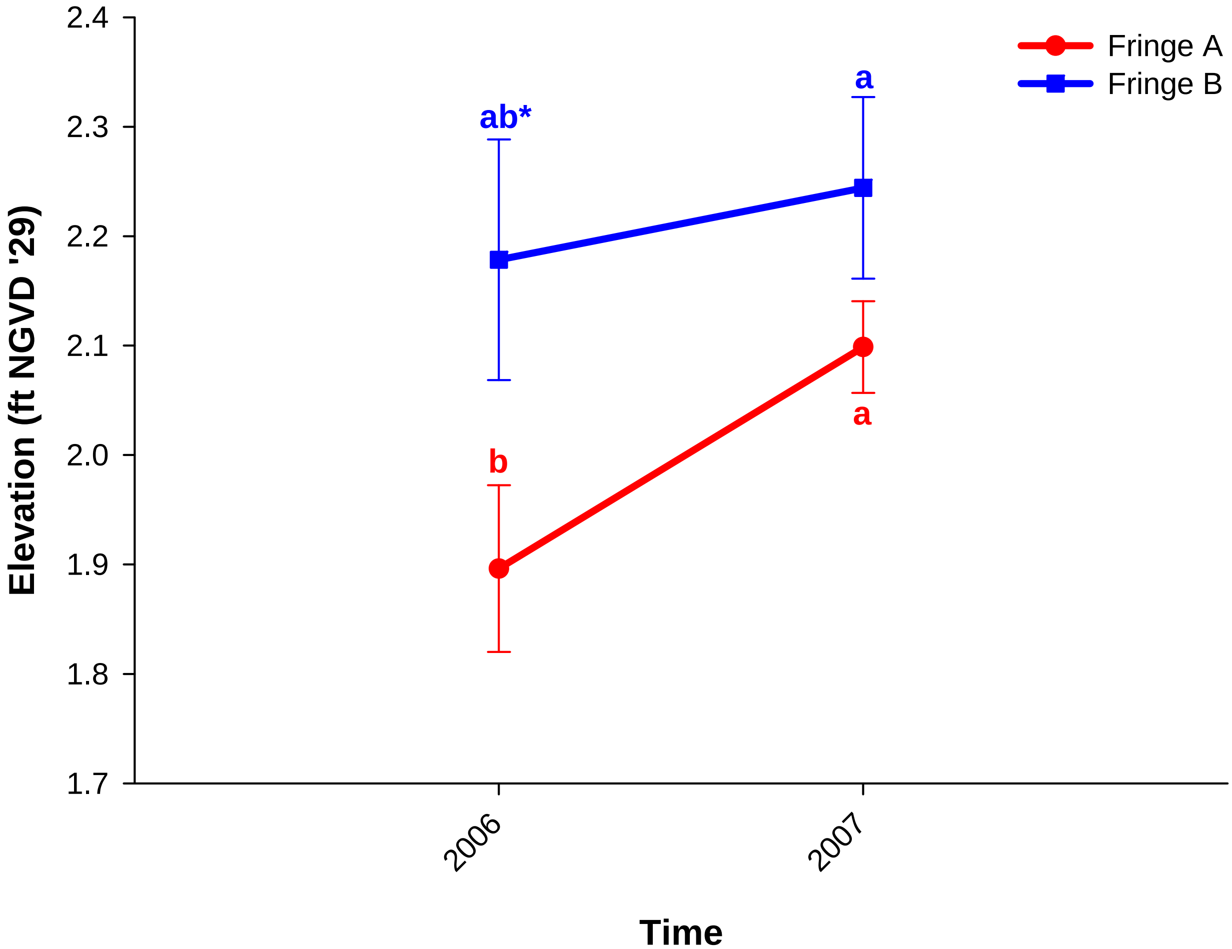


Figure 2. Plot elevations in 2006 and 2007 based on plots at the Anacostia River Fringe Wetlands Restoration Project measured in both years. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall α = 0.05). Means sharing the same letter do not differ significantly. * When all plots were included in the analysis, Fringe A and Fringe B differed significantly with respect to elevation in 2006.

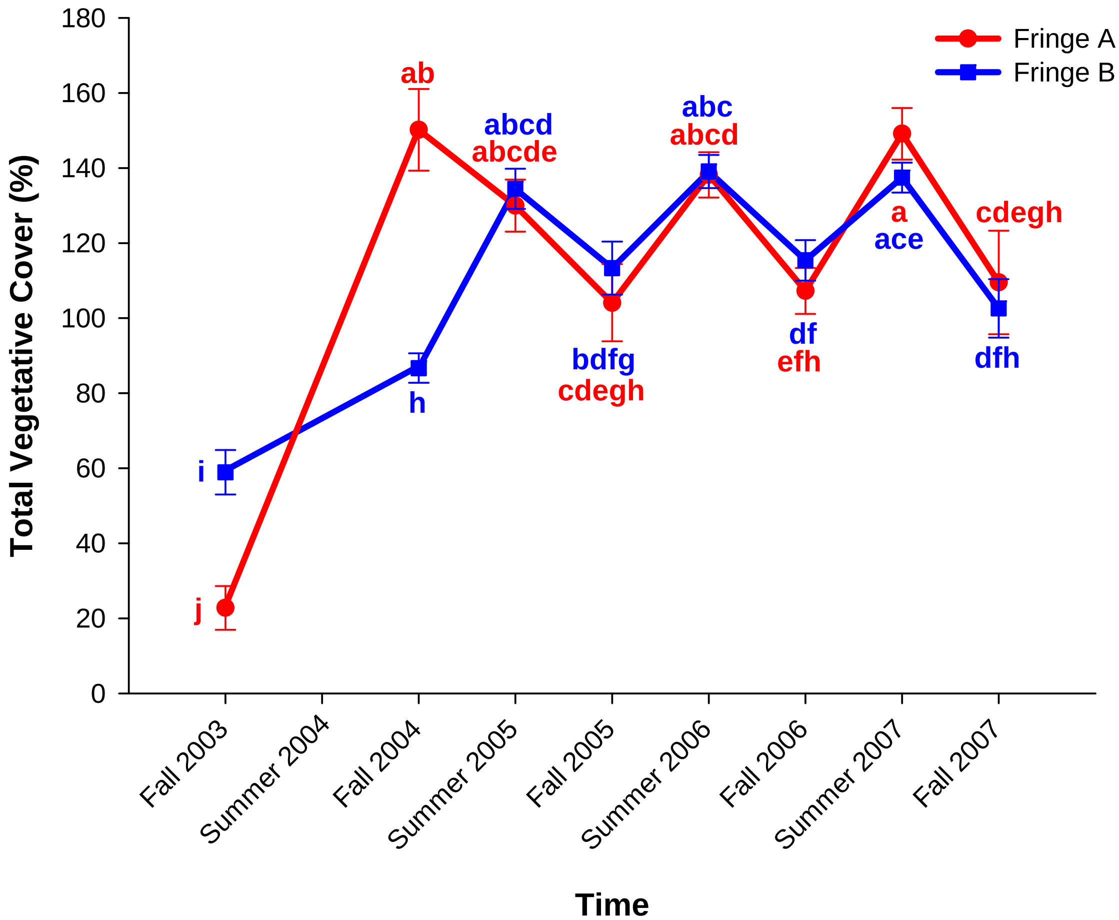


Figure 3. Total vegetative cover in plots at the Anacostia River Fringe Wetlands Restoration Project, which represents the sum of cover values for all individual species, and may therefore exceed 100 %. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall α = 0.05). Means sharing the same letter do not differ significantly.

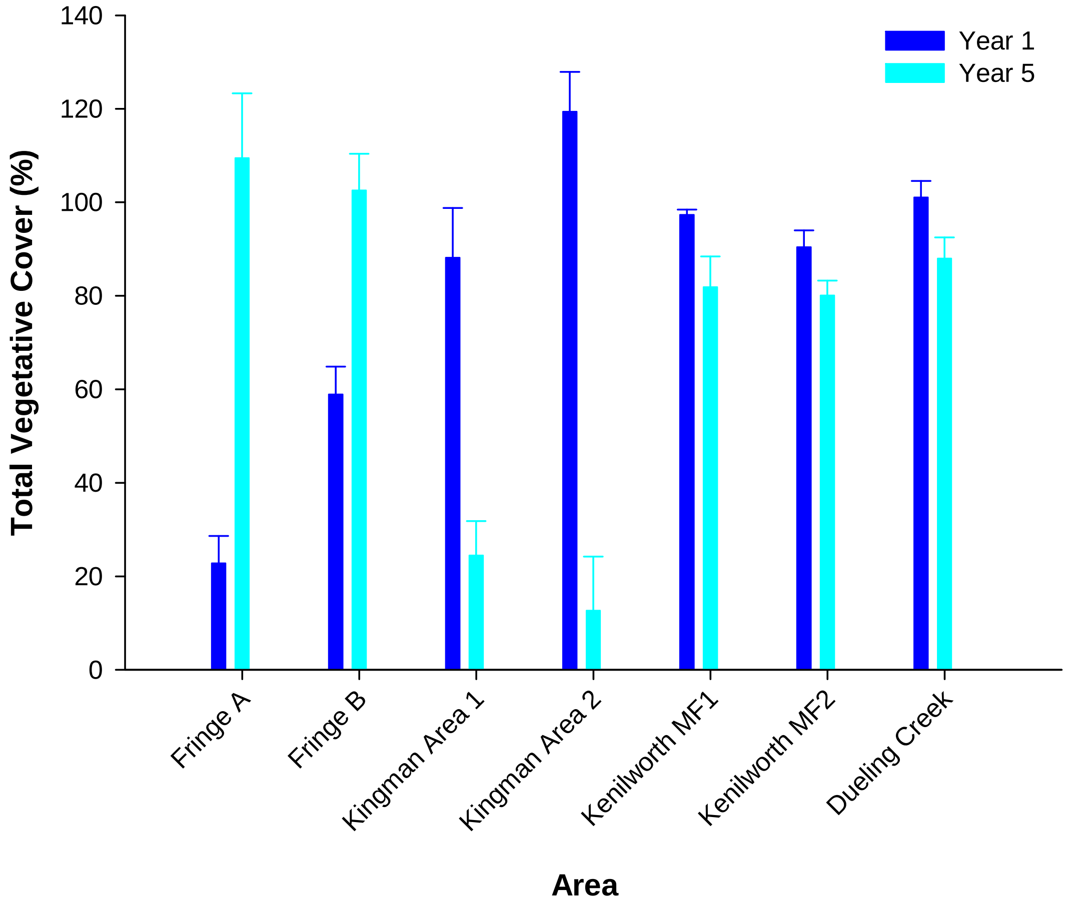


Figure 4. Total vegetative cover at the Anacostia River Fringe Wetlands Restoration Project compared to other Anacostia wetland restorations (Kenilworth Marsh and Kingman Marsh) and an Anacostia reference site (Dueling Creek). Data are presented for Years 1 and 5 of each restoration project (1993 and 1997 for Kenilworth Marsh, 2000 and 2004 for Kingman Marsh and the Dueling Creek reference site, and 2003 and 2007 for Anacostia River Fringe). Fall data are used, since summer data are not available for all years. Total vegetative cover represents the sum of cover values for all individual species, and may therefore exceed 100 %. Data points represent arithmetic means ± 1 SE.

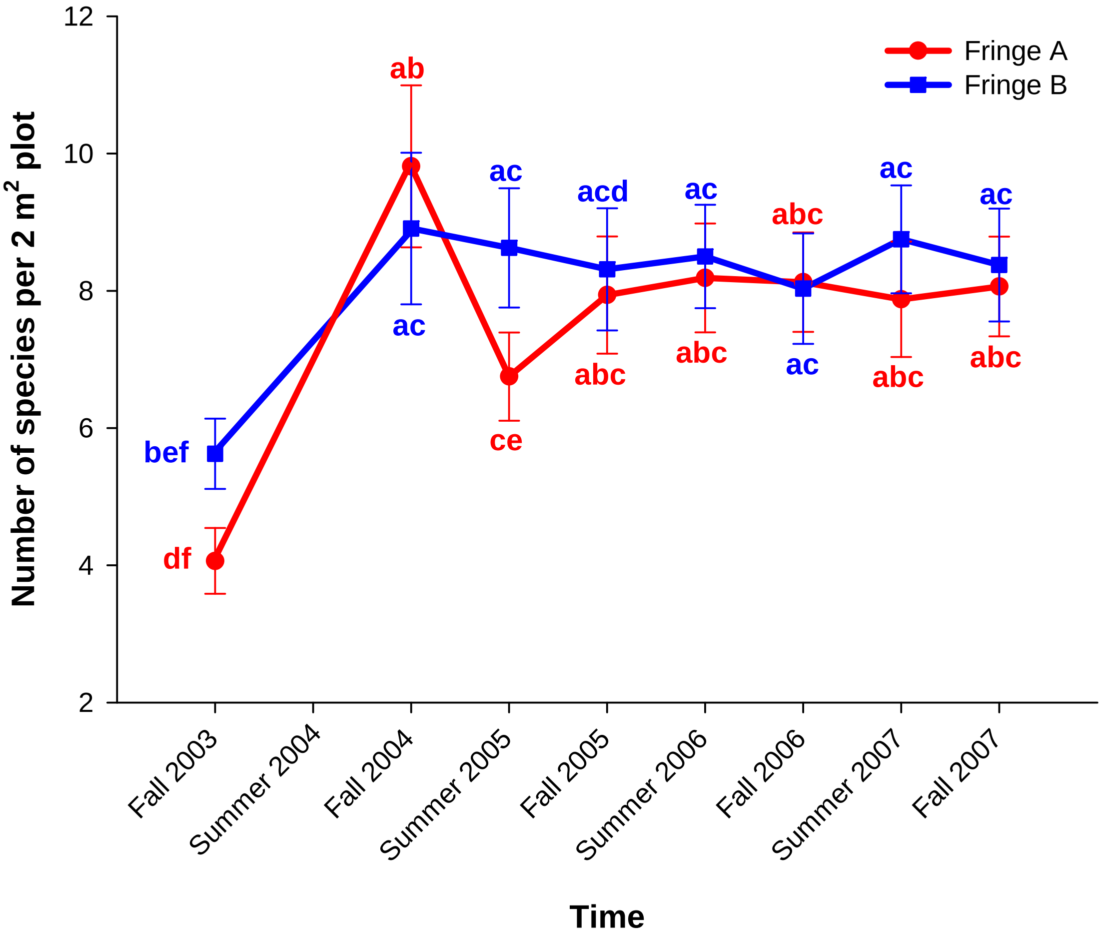


Figure 5. Species richness (number of species per 2 m^2 plot) at the Anacostia River Fringe Wetlands Restoration Project. Natural log transformation was used to improve normality of the data prior to analysis. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall $\alpha = 0.05$). Means sharing the same letter do not differ significantly.

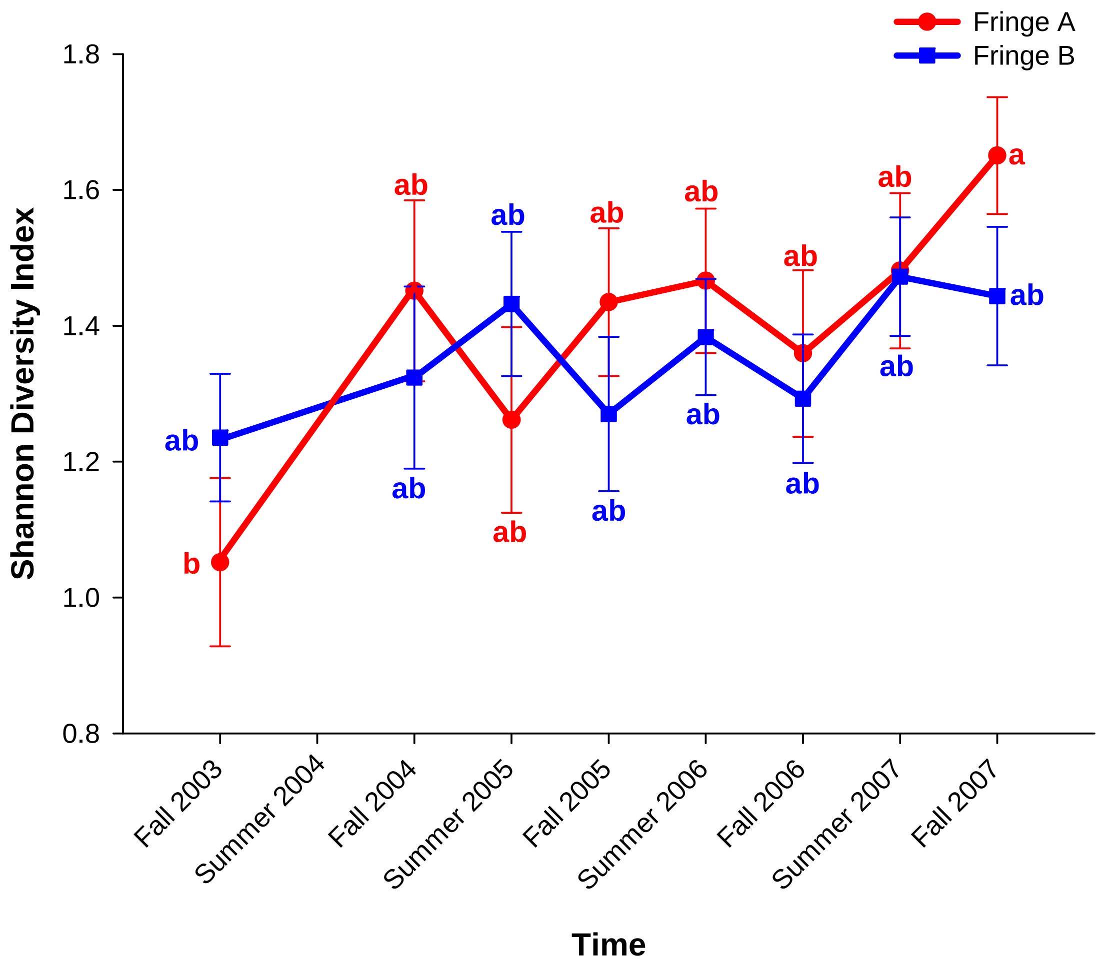


Figure 6. Shannon diversity index based on cover data from the 2 m^2 plots at the Anacostia River Fringe Wetlands Restoration. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall $\alpha = 0.05$). Means sharing the same letter do not differ significantly.

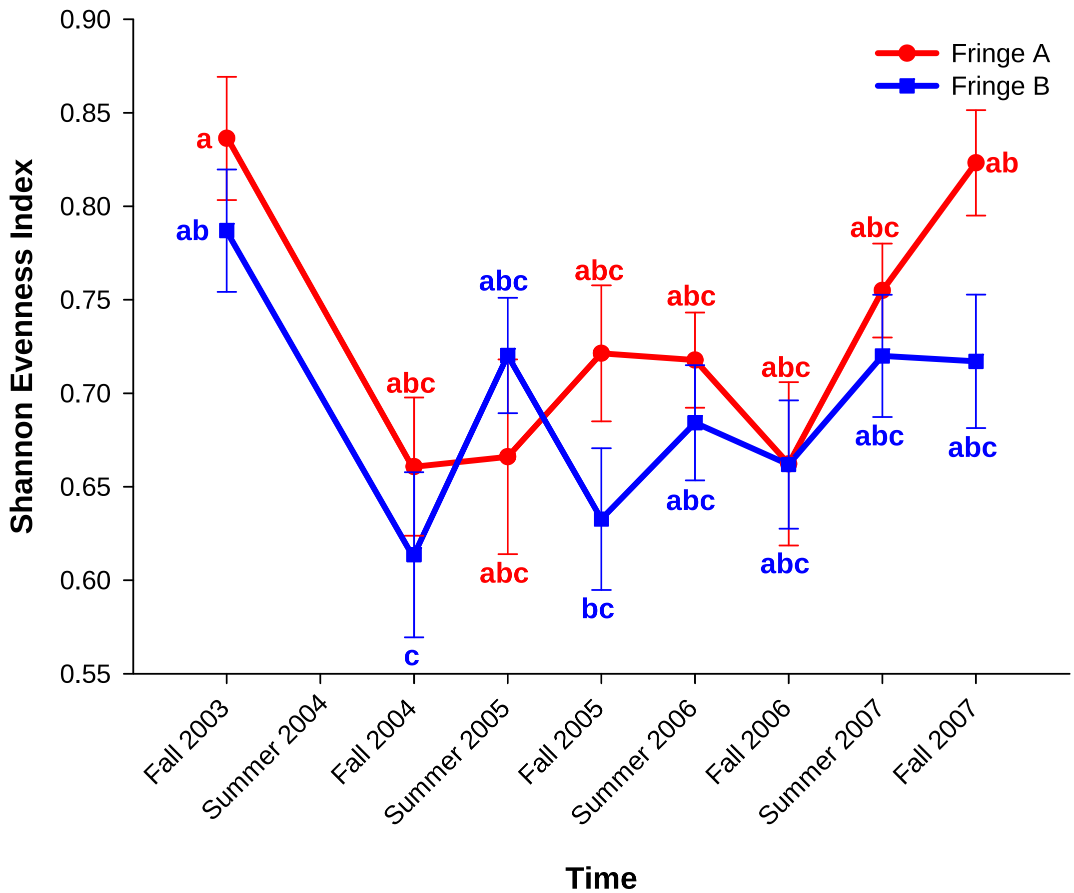


Figure 7. Shannon evenness index based on cover data from the 2 m^2 plots at the Anacostia River Fringe Wetlands Restoration. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall $\alpha = 0.05$). Means sharing the same letter do not differ significantly.

a) Fringe A

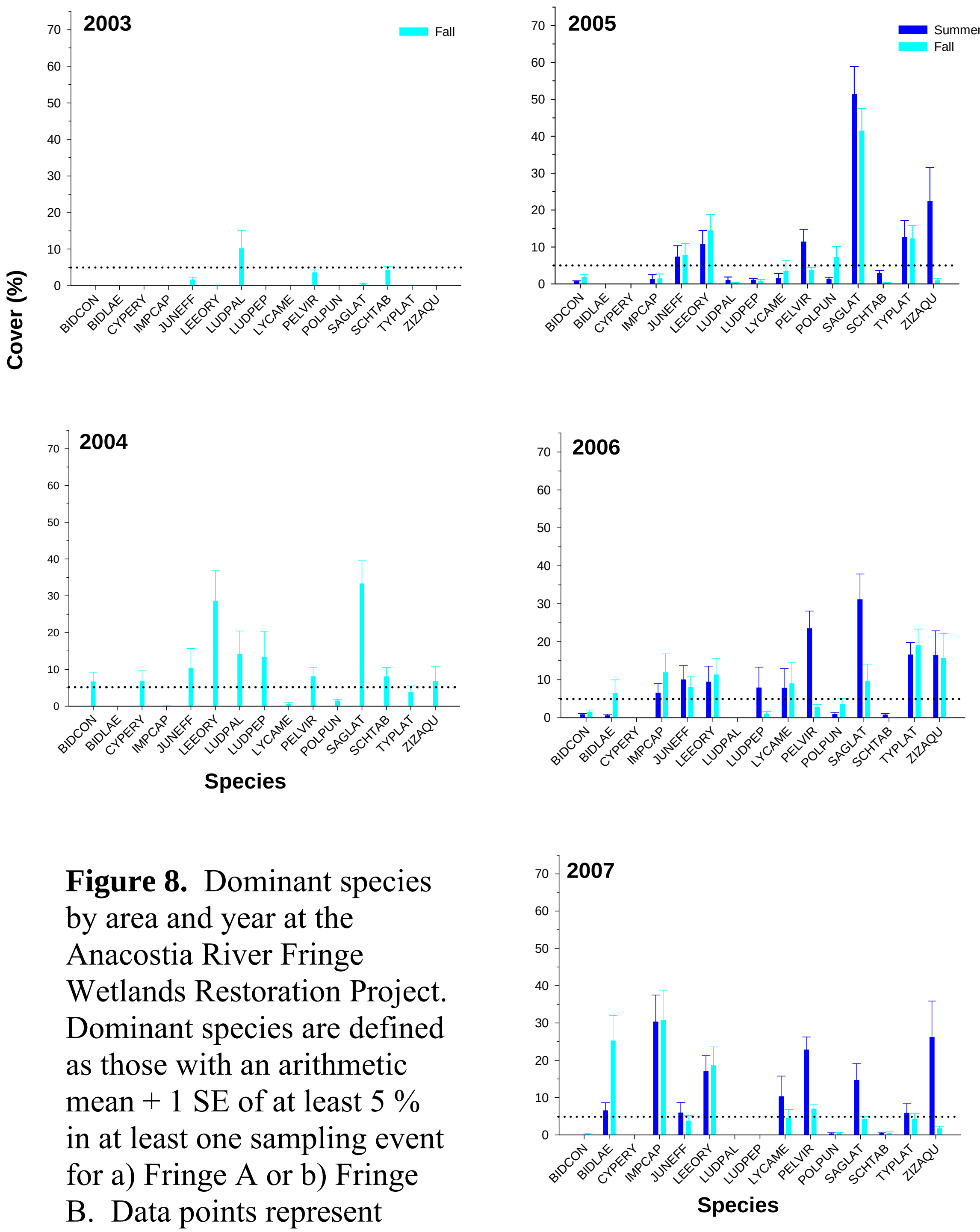


Figure 8. Dominant species by area and year at the Anacostia River Fringe Wetlands Restoration Project. Dominant species are defined as those with an arithmetic mean + 1 SE of at least 5 % in at least one sampling event for a) Fringe A or b) Fringe B. Data points represent arithmetic means ± 1 SE. Species acronyms are listed in the Appendix.

b) Fringe B

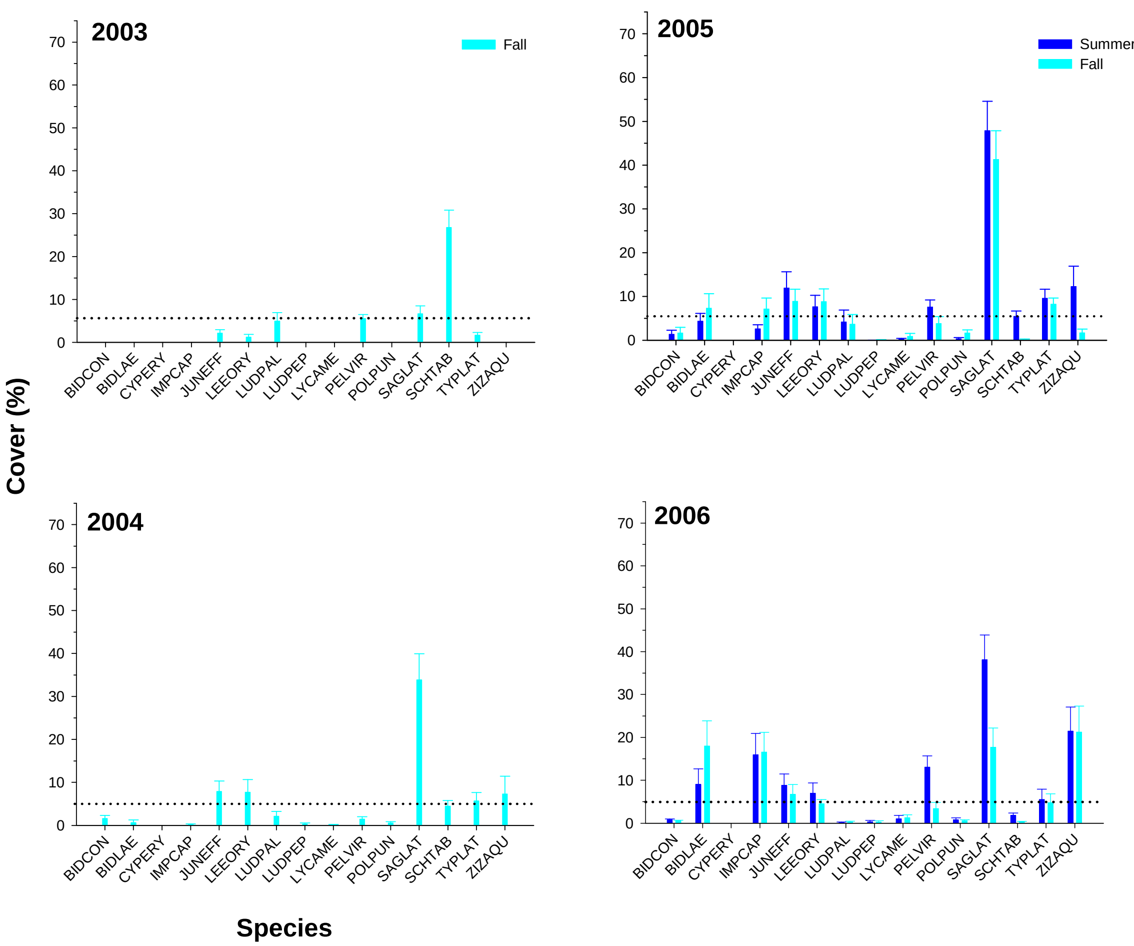
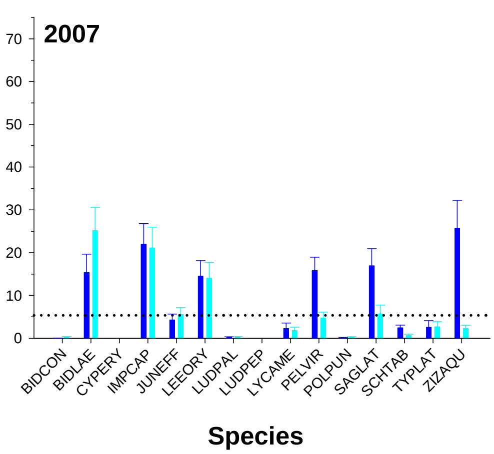


Figure 8 (Cont.). Dominant species at the Fringe Wetlands by area and year at the Anacostia River Fringe Wetlands Restoration Project. Dominant species are defined as those with an arithmetic mean + 1 SE of at least 5 % in at least one sampling event for a) Fringe A or b) Fringe B. Data points represent arithmetic means ± 1 SE. Species acronyms are listed in the Appendix.



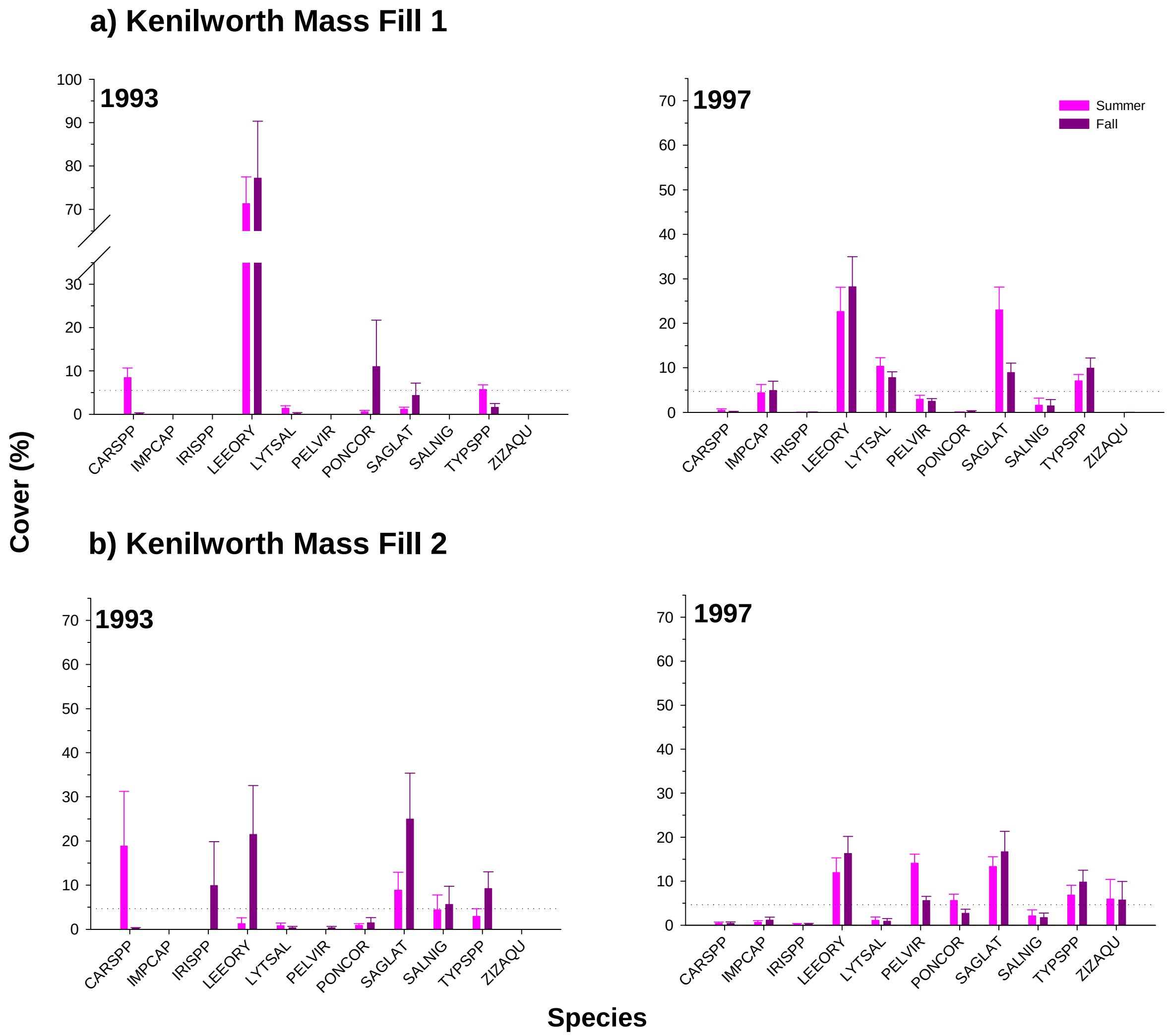


Figure 9. Dominant species at the Kenilworth Marsh reconstruction site in Years 1 (1993) and 5 (1997) of that project. Dominant species are defined as those with an arithmetic mean + 1 SE of at least 5 % in at least one sampling event for a) Kenilworth Mass Fill 1 or b) Kenilworth Mass Fill 2. Data points represent arithmetic means ± 1 SE. Species acronyms are listed in the Appendix.

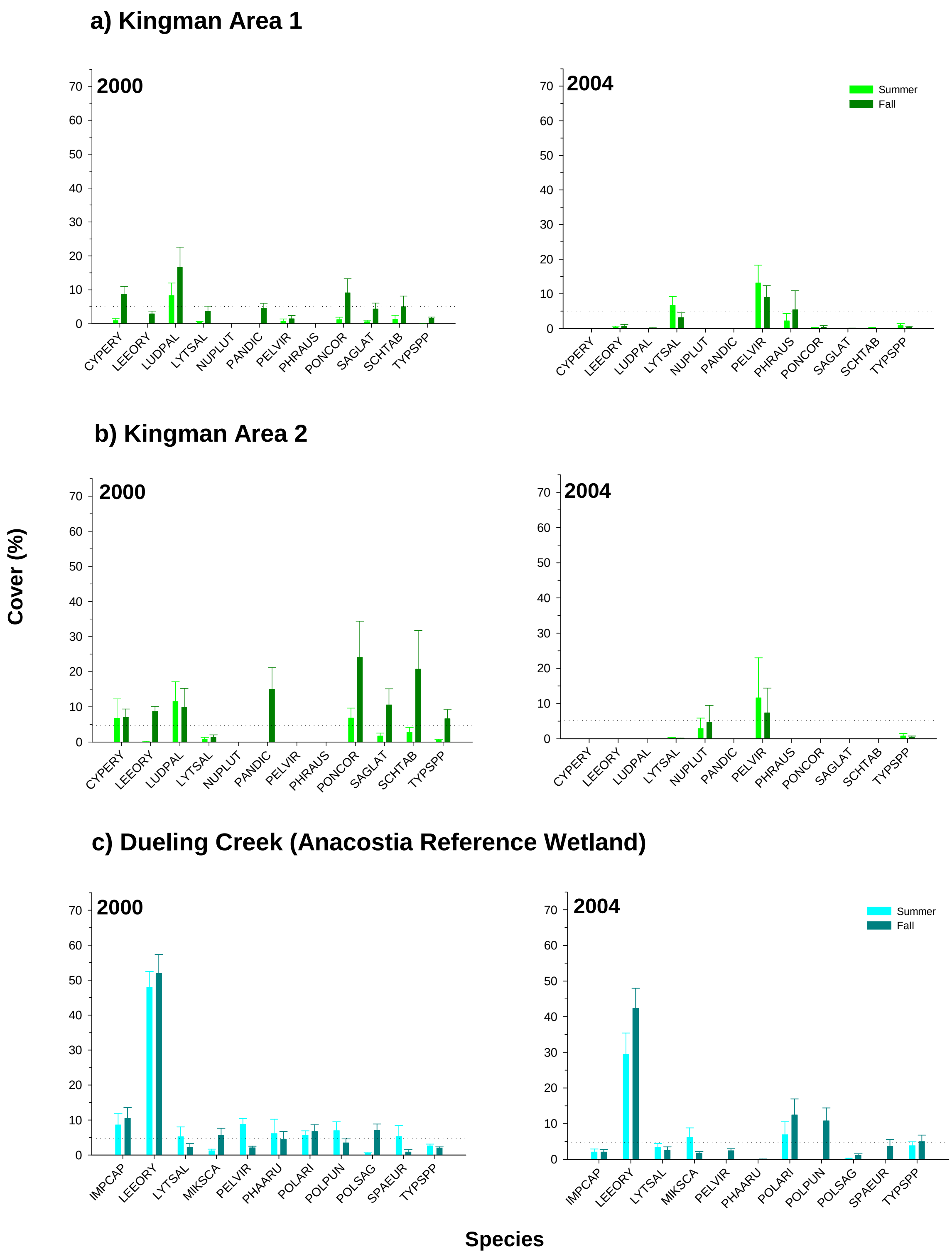
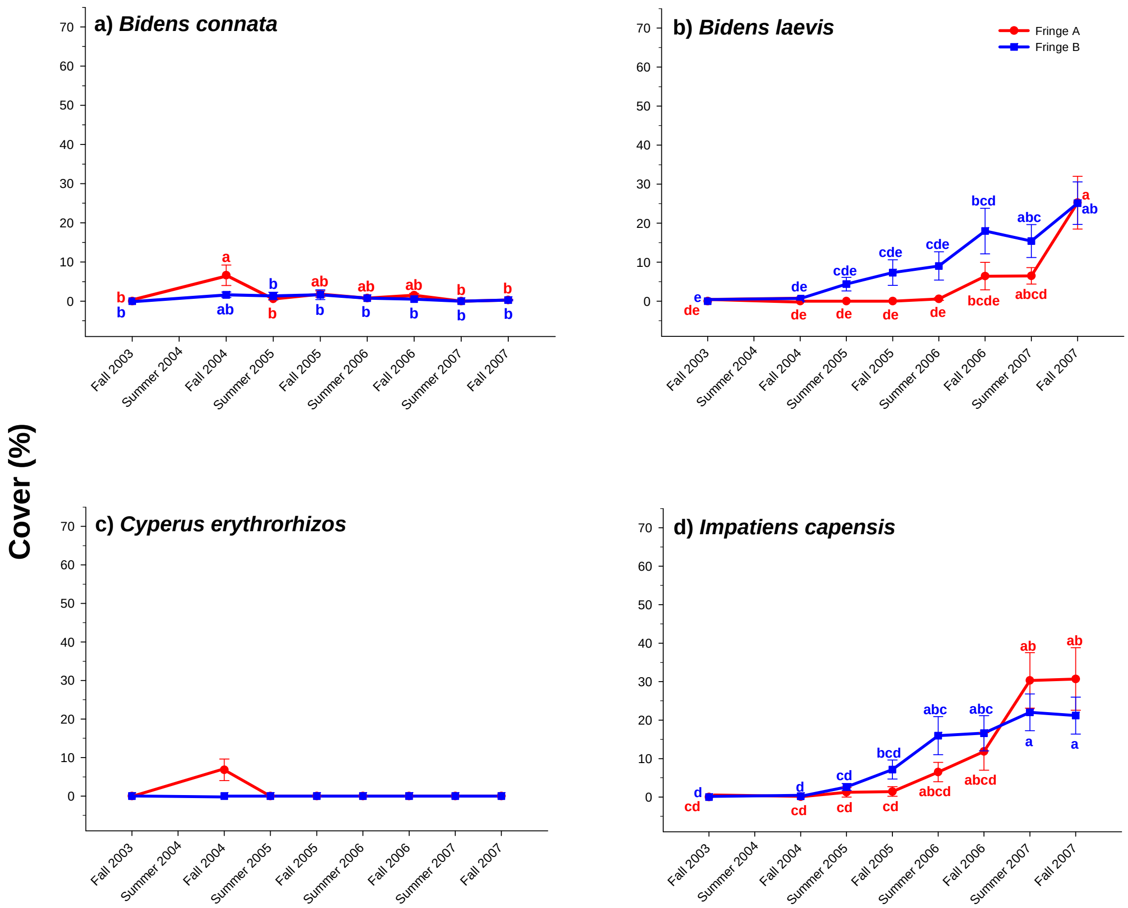


Figure 10. Dominant species at the Kingman Marsh reconstruction site and Dueling Creek, a nearby reference wetland, in Years 1 (2000) and 5 (2004) of that project. Dominant species are defined as those with an arithmetic mean + 1 SE of at least 5 % in at least one sampling event for a) Kingman Area 1 or b) Kingman Area 2. Dueling Creek dominants are presented in c). Data points represent arithmetic means ± 1 SE. Species acronyms are listed in the Appendix.



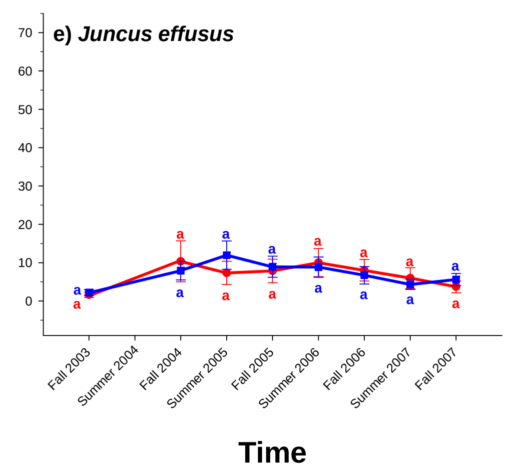


Figure 11. Individual dominant species cover over time at the Anacostia River Fringe Wetlands Restoration Project. Natural log transformation was used to improve normality of the data prior to analysis. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall $\alpha = 0.05$). Means sharing the same letter do not differ significantly. Graphs with no labels indicate that data did not meet ANOVA normality assumptions even after transformation and so no ANOVA was performed.

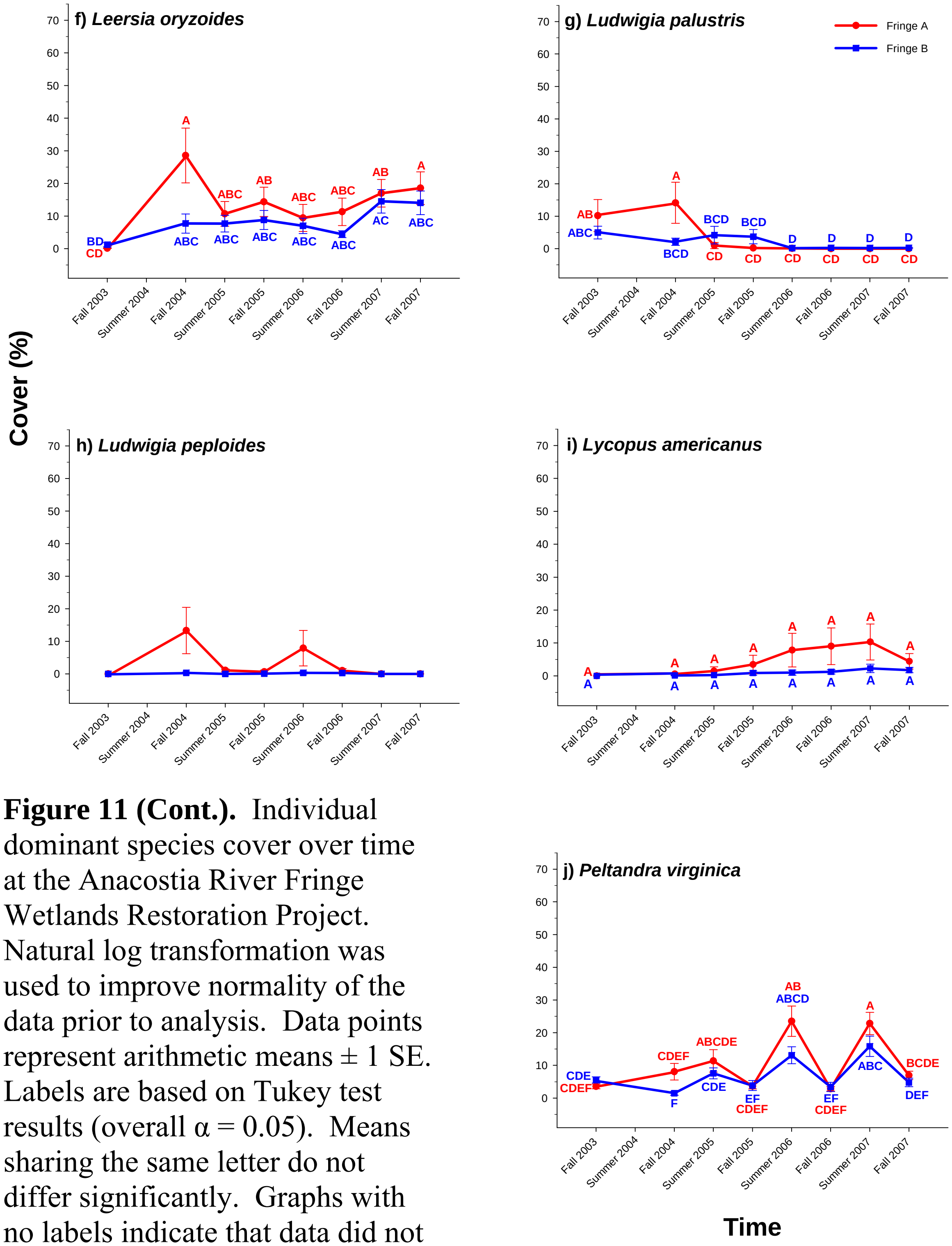
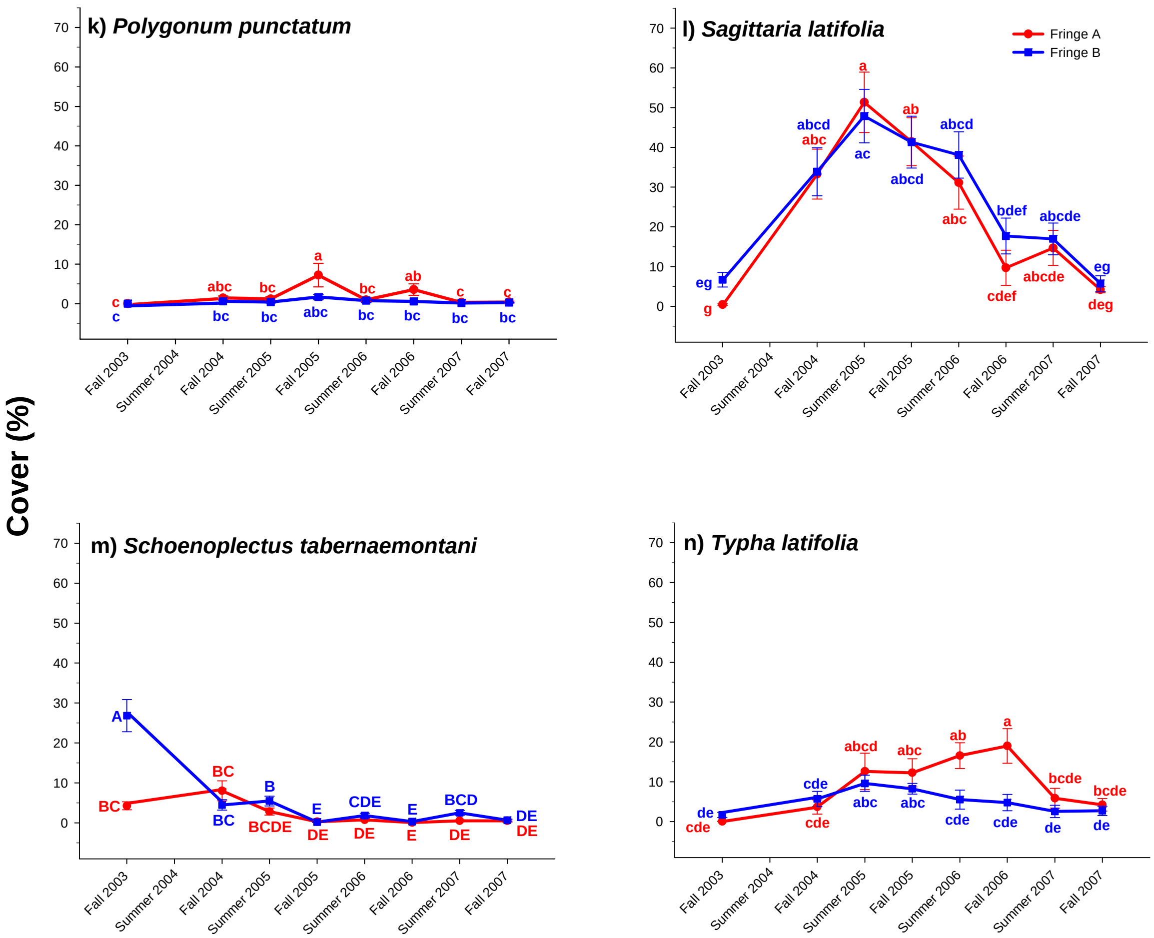


Figure 11 (Cont.). Individual dominant species cover over time at the Anacostia River Fringe Wetlands Restoration Project. Natural log transformation was used to improve normality of the data prior to analysis. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall α = 0.05). Means sharing the same letter do not differ significantly. Graphs with no labels indicate that data did not meet ANOVA normality assumptions even after transformation and so no ANOVA was performed.



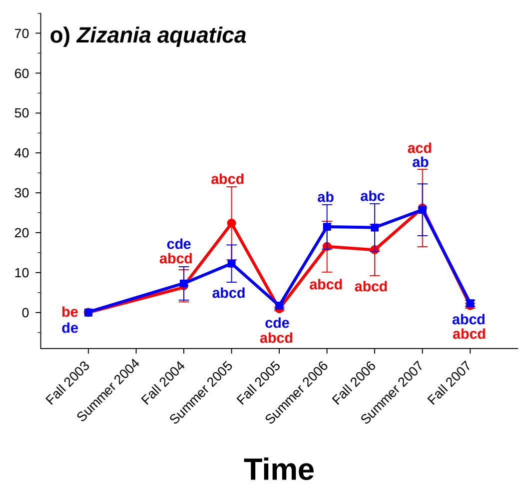


Figure 11 (Cont.). Individual dominant species cover over time at the Anacostia River Fringe Wetlands Restoration Project. Natural log transformation was used to improve normality of the data prior to analysis. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall $\alpha = 0.05$). Means sharing the same letter do not differ significantly. Graphs with no labels indicate that data did not meet ANOVA normality assumptions even after transformation and so no ANOVA was performed.

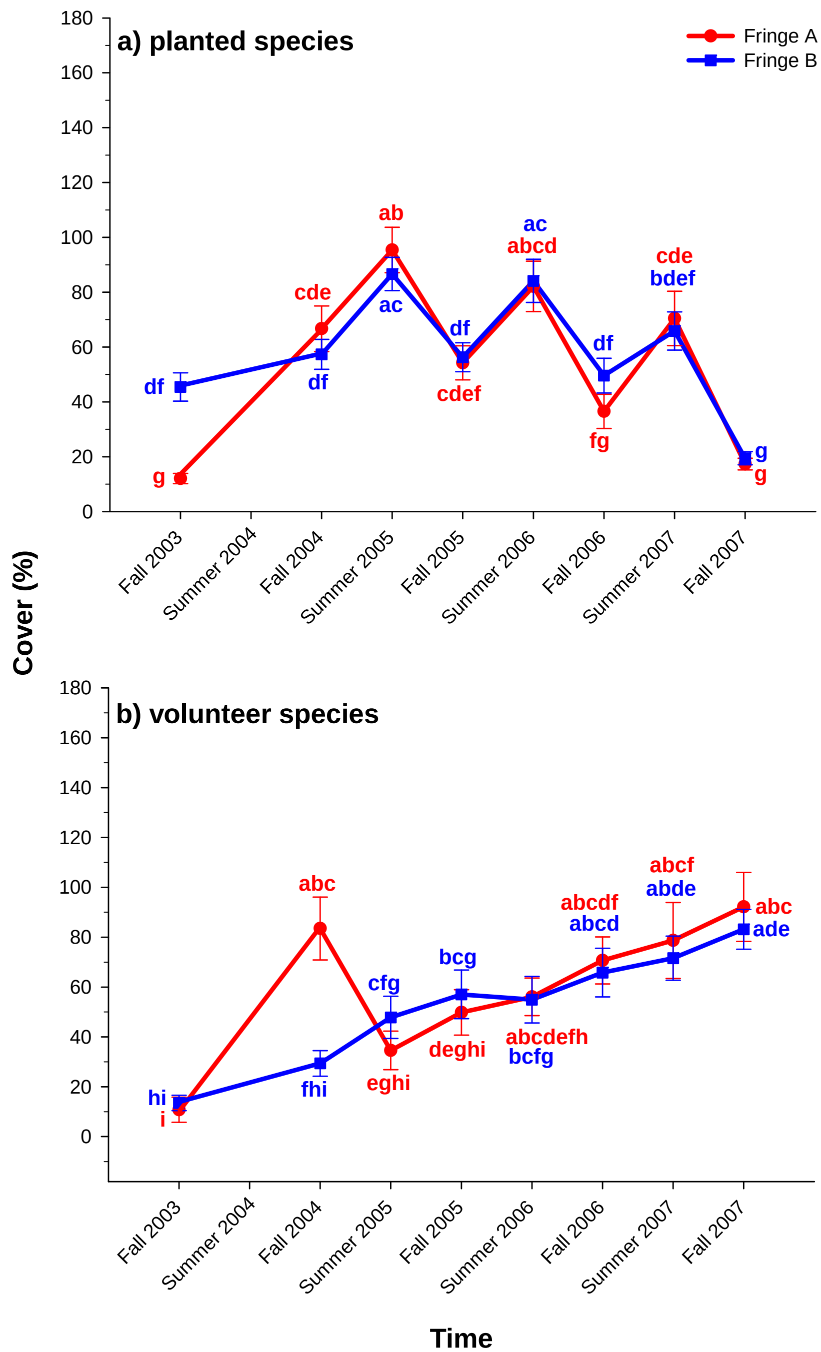


Figure 12. Cover contributed by planted and volunteer species at the Anacostia River Fringe Wetlands Restoration Project. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall $\alpha = 0.05$). Means sharing the same letter do not differ significantly.

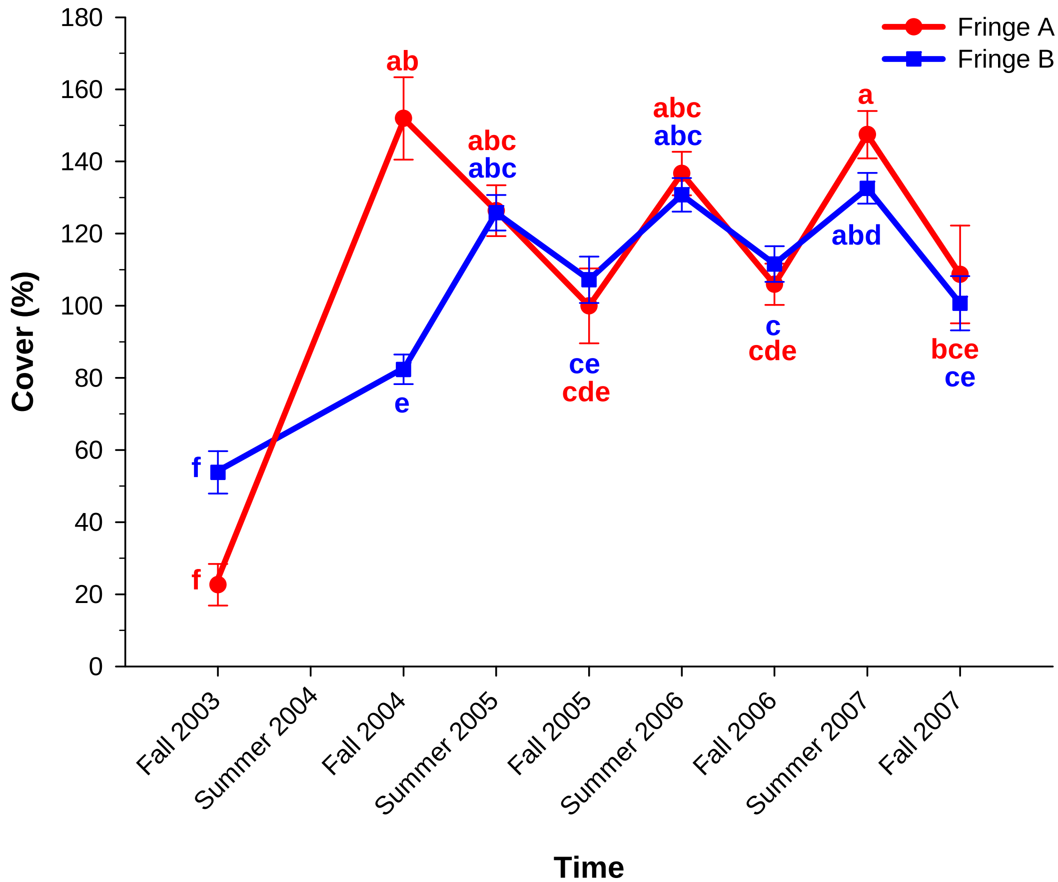


Figure 13. Cover contributed by wetland species (Wetland Indicator Status of FACW or wetter) at the Anacostia River Fringe Wetlands Restoration Project. Classifications based on the PLANTS database (USDA, NRCS 2008). Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall $\alpha = 0.05$). Means sharing the same letter do not differ significantly.

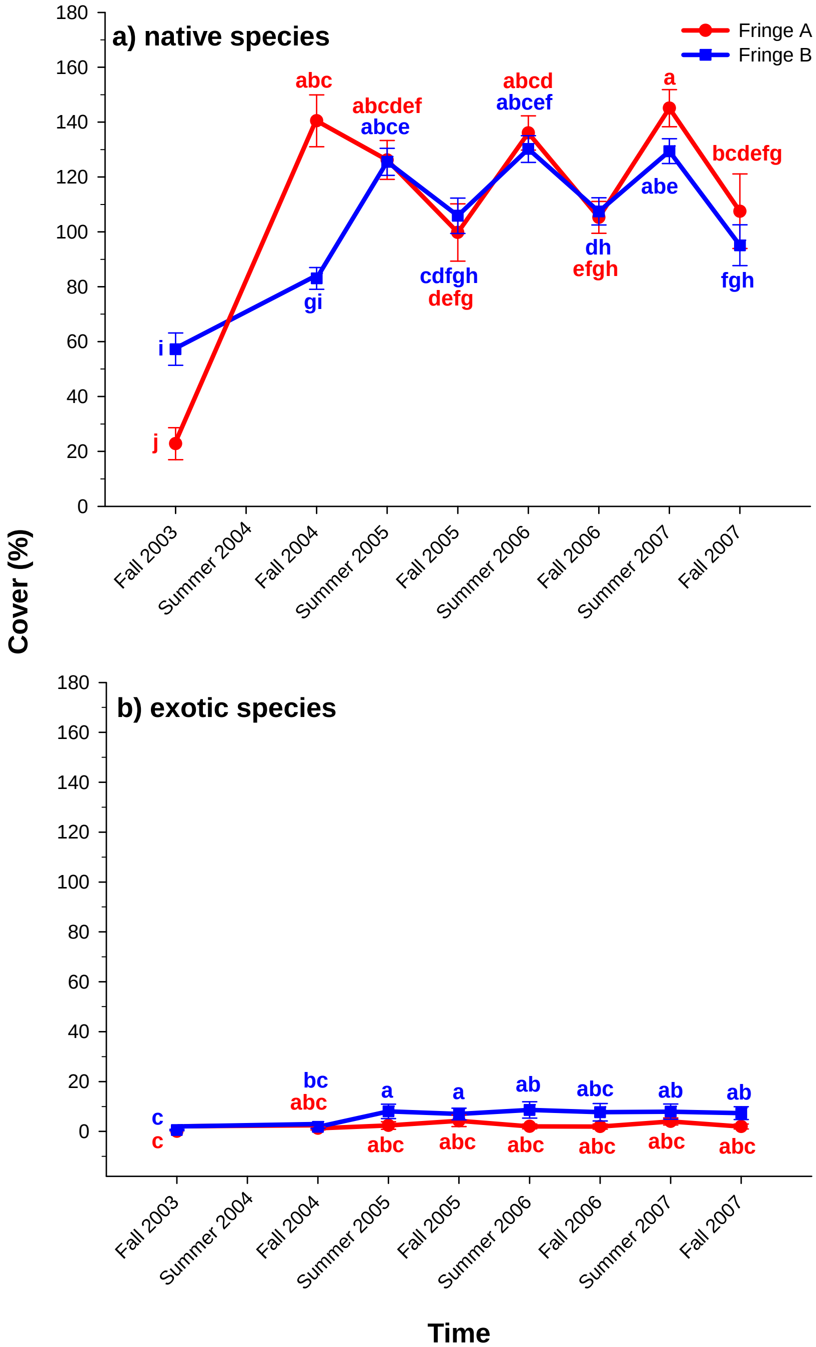


Figure 14. Cover contributed by a) native species and b) exotic species at the Anacostia River Fringe Wetlands Restoration Project. Classifications based on the PLANTS database (USDA, NRCS 2008). Natural log transformation was used to improve normality of the exotics data set prior to analysis. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall $\alpha = 0.05$). Means sharing the same letter do not differ significantly.

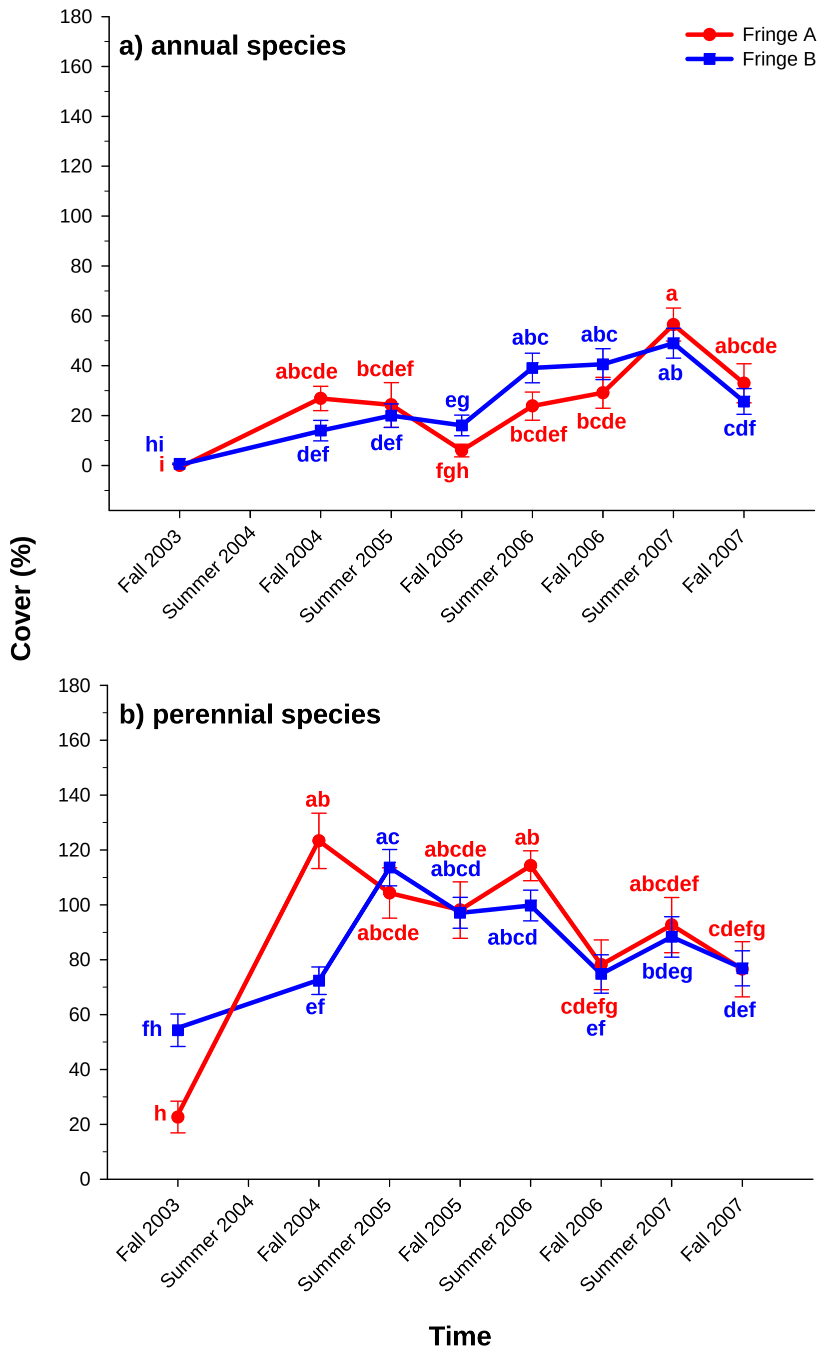


Figure 15. Cover contributed by a) annual species and b) perennial species at the Anacostia River Fringe Wetlands Restoration Project. Classifications based on the PLANTS database (USDA, NRCS 2008). Natural log transformation was used to improve normality of the annuals data set prior to analysis. Data points represent arithmetic means ± 1 SE. Labels are based on Tukey test results (overall $\alpha = 0.05$). Means sharing the same letter do not differ significantly.

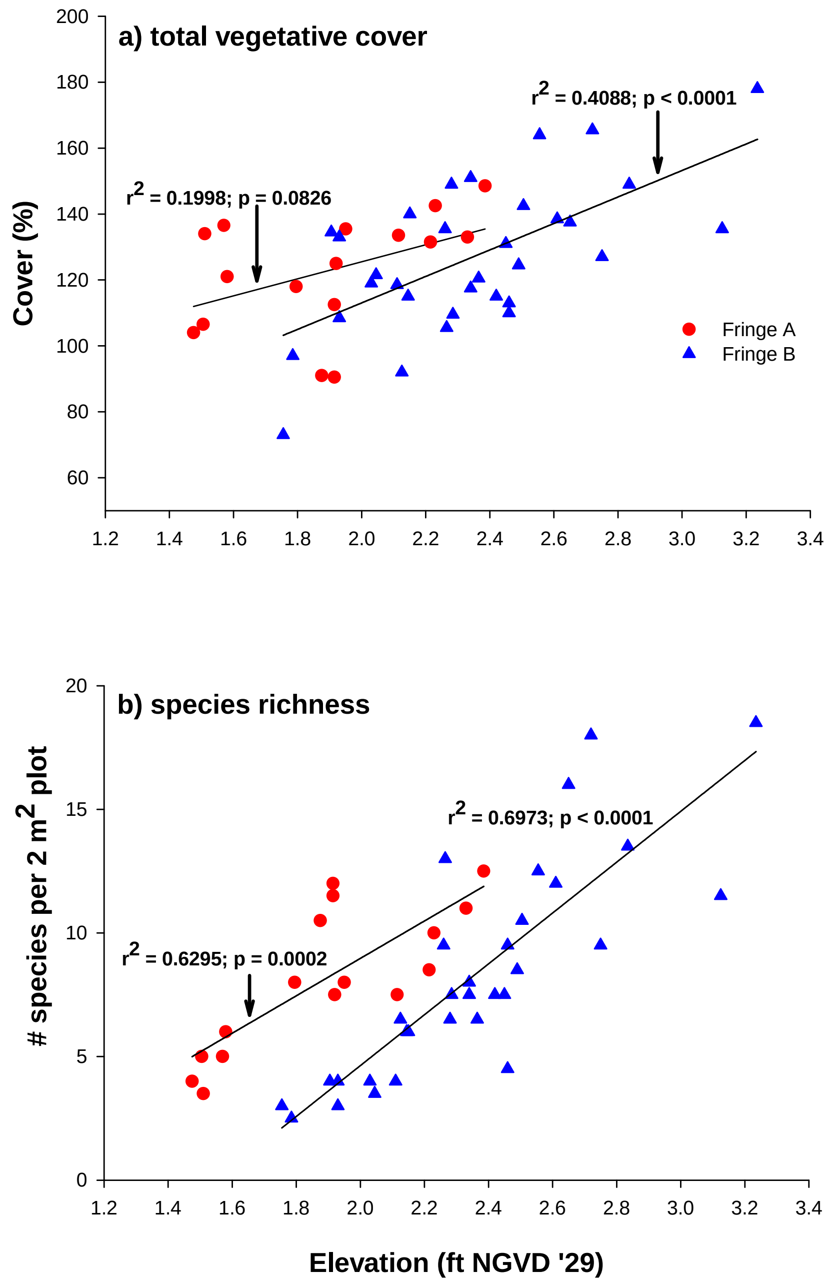


Figure 16. Total vegetative cover and species richness (number of species per $2m^2$ plot) versus elevation at the Anacostia River Fringe Wetlands Restoration Project. Linear regressions were performed on elevation and vegetation data collected in 2006.

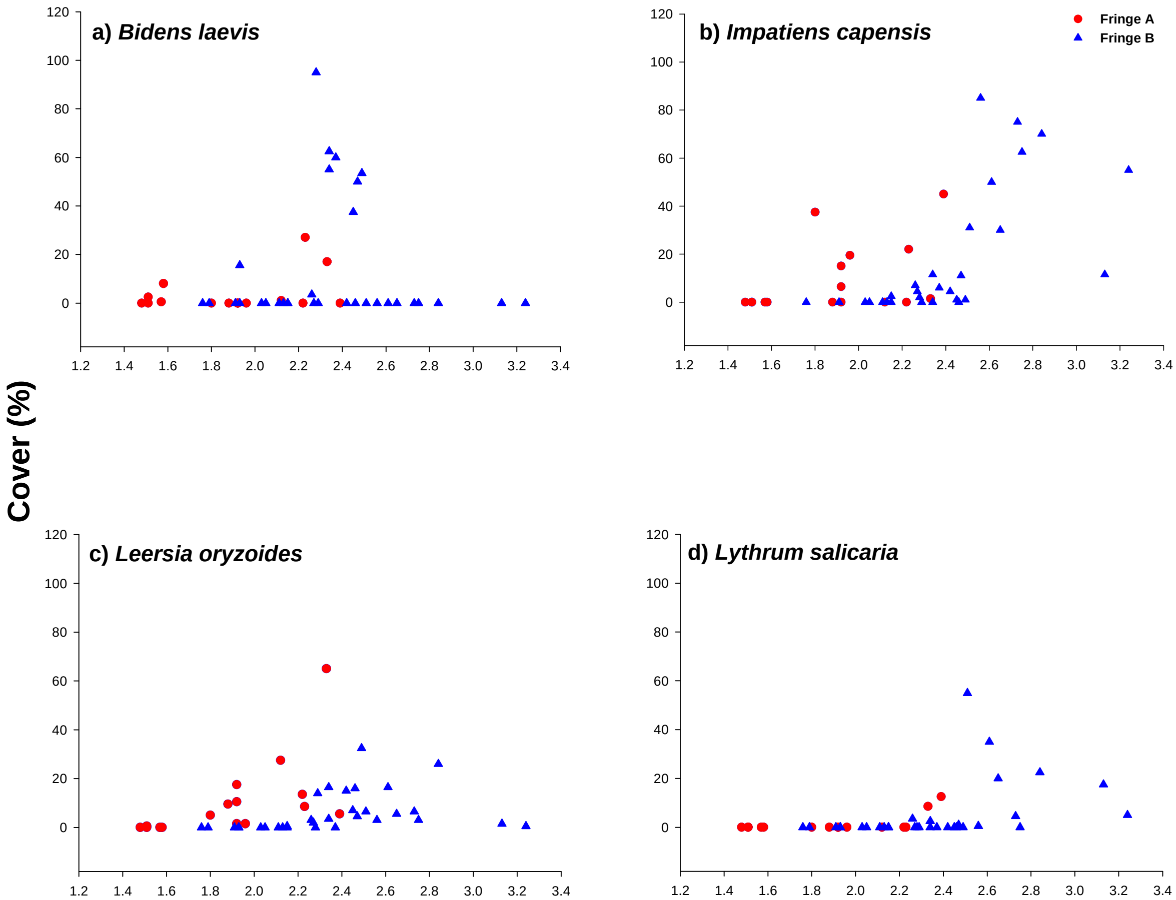
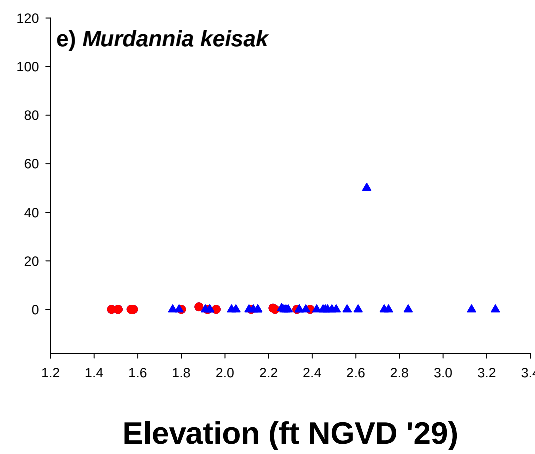


Figure 17. Dominant species and species of special concern cover versus elevation at the Anacostia River Fringe Wetlands Restoration Project. Linear regressions were performed on elevation and vegetation data collected in 2006.



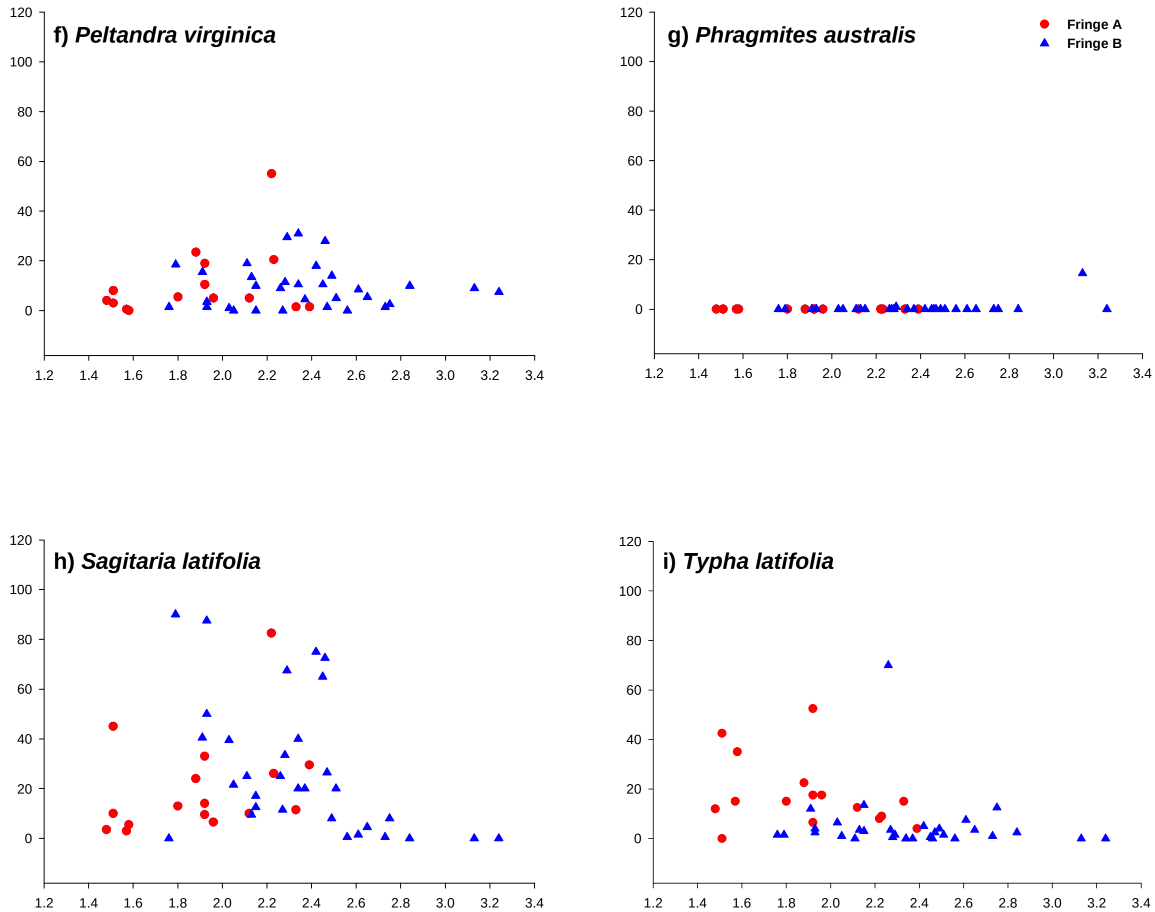
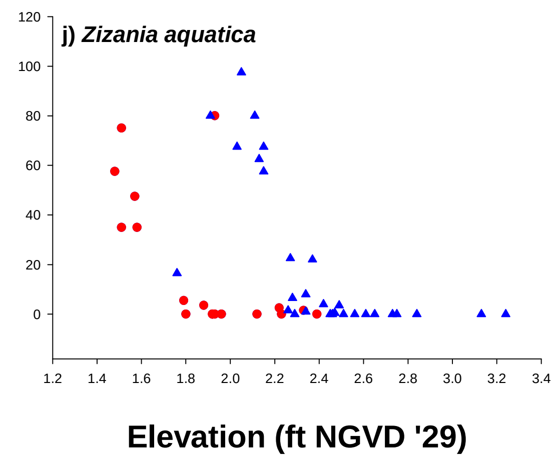


Figure 17 (Cont.). Dominant species and species of special concern cover versus elevation at the Anacostia River Fringe Wetlands Restoration Project. Linear regressions were performed on elevation and vegetation data collected in 2006.



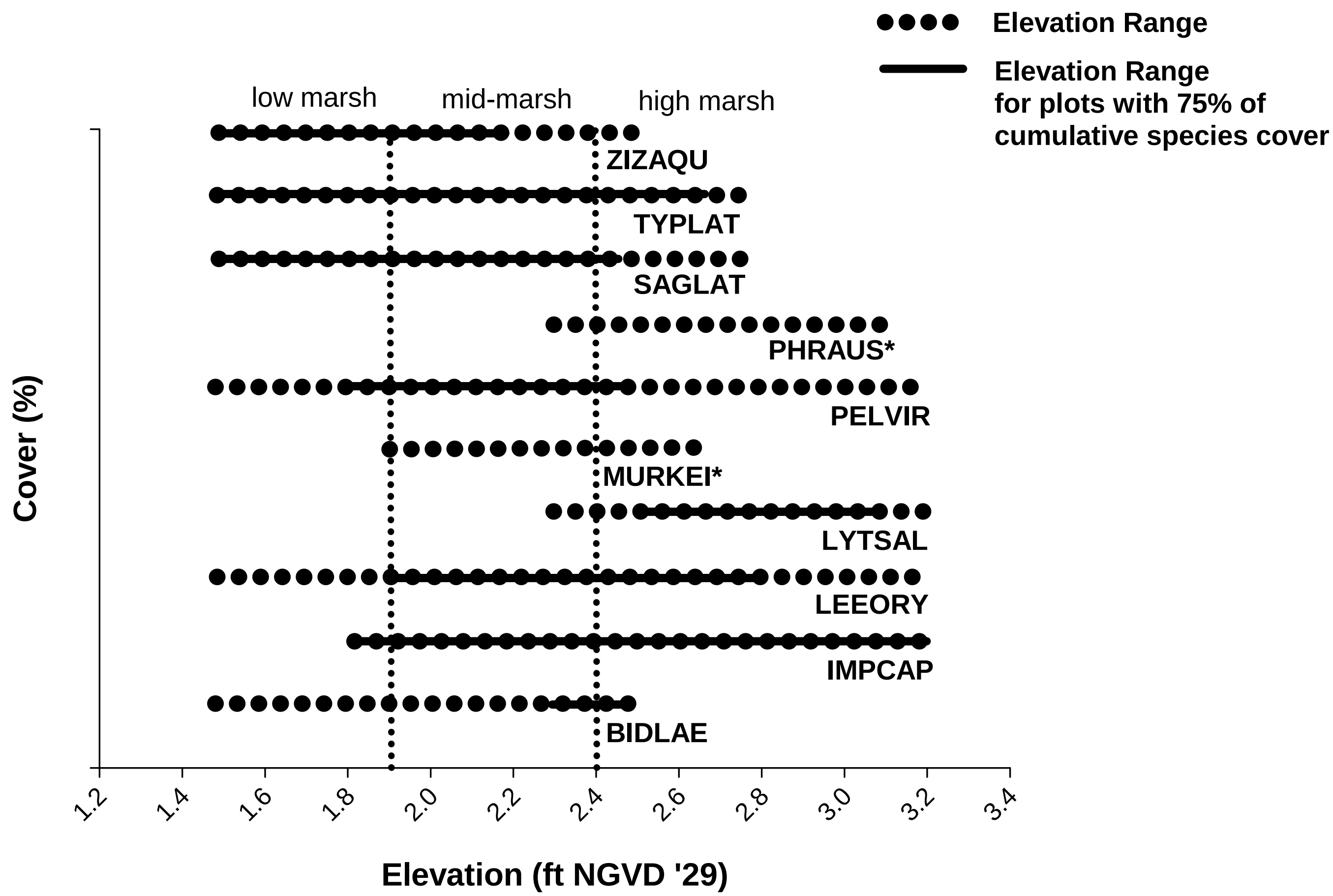


Figure 18. Elevation ranges for key dominant species and species of special concern at the Anacostia River Fringe Wetlands Restoration Project. Solid lines illustrate zones of concentration within the overall range (i.e., elevation ranges for plots with 75 % of cumulative cover). Linear regressions were performed on elevation and vegetation data collected in 2006. * Included as species of special concern, but no zone of concentration is presented due to small sample size. Low, mid- and high marsh ranges are based on a mean high water of 2.2 ft NGVD ’29 and additional information provided in USACE planning documents for the Fringe Wetlands and Kingman Marsh. Species acronyms are listed in the Appendix.

APPENDIX

Appendix. Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	Family	Years Observed				
				2003	2004	2005	2006	2007
Acer negundo L.	boxelder	ACENEG	Aceraceae		x	x	x	x
Acer rubrum L.	red maple	ACERUB	Aceraceae		x	x	x	x
Acer saccharinum L.	silver maple	ACESAC	Aceraceae		x		x	x
Alisma subcordatum Raf.	American water plantain	ALISUB	Alismataceae	x	x	x	x	x
Amaranthus cannabinus (L.) Sauer	tidalmarsh amaranth	AMACAN	Amaranthaceae		x	x	x	x
Ambrosia trifida L.	great ragweed	AMBTRI	Asteraceae					x
Apios americana Medik.	groundnut	APIAME	Fabaceae			x	x	x
Artemisia annua L.	sweet sagewort	ARTANN	Asteraceae		x			
Arthraxon hispidus (Thunb.) Makino	small carpgrass	ARTHIS	Poaceae			x		
Bidens aristosa (Michx.) Britton	bearded beggarticks	BIDARI	Asteraceae		x	x		
Bidens connata Muhl. ex Willd.	purplestem beggarticks	BIDCON	Asteraceae	x	x	x	x	x
Bidens frondosa L.	devil's beggartick	BIDFRO	Asteraceae	x	x	x	x	x
Bidens laevis (L.) Britton, Sterns & Poggenb.	smooth beggartick	BIDLAE	Asteraceae	x	x	x	x	x
Boehmeria cylindrica (L.) Sw.	smallspike false nettle	BOECYL	Urticaceae	x	x	x	x	x
Calystegia sepium (L.) R. Br.	hedge false bindweed	CALSEP	Convolvulaceae					x
Carex atlantica L. H. Bailey ssp. *atlantica*	prickly bog sedge	CARATL	Cyperaceae		x	x	x	
Carex conjuncta Boott	soft fox sedge	CARCON	Cyperaceae				x	
Carex crinita Lam.	fringed sedge	CARCRI	Cyperaceae				x	x
Carex frankii Kunth	Frank's sedge	CARFRA	Cyperaceae		x	x	x	x
Carex laevivaginata (Kük.) Mack.	smoothsheath sedge	CARLAE	Cyperaceae			x		x
Carex lurida (Wahlenb.)	shallow sedge	CARLUR	Cyperaceae		x	x	x	x
Carex scoparia Schkuhr ex Willd.	broom sedge	CARSCO	Cyperaceae				x	x
Carex stipata Muhl. ex Willd.	awlfruit sedge	CARSTI	Cyperaceae				x	
Carex tribuloides Wahlenb.	blunt broom sedge	CARTRI	Cyperaceae		x	x	x	x
Carex vulpinoidea Michx.	fox sedge	CARVUL	Cyperaceae			x	x	x
Cephalanthus occidentalis L.	common buttonbush	CEPOCC	Rubiaceae					x
Chenopodium leptophyllum (Moq.) Nutt. ex S. Watson	narrowleaf goosefoot	CHELEP	Chenopodiaceae		x			
Cicuta maculata L.	spotted water hemlock	CICMAC	Apiaceae			x	x	x

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	Family	Years Observed				
				2003	2004	2005	2006	2007
Clematis terniflora DC.	sweet autumn virginsbower	CLETER	Ranunculaceae					x
Commelina virginica L.	Virginia dayflower	COMVIR	Commelinaceae					x
Conoclinium coelestinum (L.) DC.	blue mistflower	CONCOE	Asteraceae			x	x	
Conyza canadensis (L.) Cronquist var. *canadensis*	Canadian horseweed	CONCAN	Asteraceae		x			x
Cuscuta gronovii Willd. ex Schult.	scaldweed	CUSGRO	Cuscutaceae		x	x	x	x
Cyperus erythrorhizos Muhl.	redroot flatsedge	CYPERY	Cyperaceae	x	x			x
Cyperus flavescens L.	yellow flatsedge	CYPFLA	Cyperaceae		x	x		x
Cyperus odoratus L.	fragrant flatsedge	CYPODO	Cyperaceae	x	x	x		
Cyperus strigosus L.	strawcolored flatsedge	CYPSTR	Cyperaceae	x	x	x	x	x
Digitaria sanguinalis (L.) Scop.	hairy crabgrass	DIGSAN	Poaceae	x				
Echinochloa crus-galli (L.) P. Beauv.	barnyardgrass	ECHCRU	Poaceae	x	x	x	x	x
Echinochloa walteri (Pursh) A. Heller	coast cockspur grass	ECHWAL	Poaceae			x		
Eclipta prostrata (L.) L.	false daisy	ECLPRO	Asteraceae	x	x	x	x	x
Eleocharis obtusa (Willd.) Schult.	blunt spikerush	ELEOBT	Cyperaceae	x	x	x		x
Eleusine indica (L.) Gaertn.	Indian goosegrass	ELEIND	Poaceae	x				
Elymus virginicus L.	Virginia wildrye	ELYVIR	Poaceae		x	x	x	x
Epilobium coloratum Biehler	purpleleaf willowherb	EPICOL	Onagraceae		x	x	x	x
Eragrostis sp. Von Wolf	lovegrass	ERASP	Poaceae	x				
Erechtites hieracifolia (L.) Raf. ex DC var. *hieracifolia*	American burnweed	EREHIE	Asteraceae		x	x		
Eupatoriadelphus fistulosus (Barratt) King & H. Rob.	trumpetweed	EUPFIS	Asteraceae					x
Eupatorium serotinum Michx.	lateflowering boneset	EUPSER	Asteraceae		x	x	x	x
Euthamia graminifolia (L.) Nutt.	flat-top goldentop	EUTGRA	Asteraceae			x		
Fraxinus pennsylvanica Marsh.	green ash	FRAPEN	Oleaceae			x		x
Galium tinctorium (L.) Scop.	stiff marsh bedstraw	GALTIN	Rubiaceae		x	x	x	
Helenium autumnale L.	common sneezeweed	HELAUT	Asteraceae					x
Hibiscus moscheutos L.	crimsoneyed rosemallow	HIBMOS	Malvaceae	x	x	x	x	x
Impatiens capensis Meerb.	jewelweed	IMPCAP	Balsminaceae		x	x	x	x

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	Family	Years Observed				
				2003	2004	2005	2006	2007
Iris pseudacorus L.	paleyellow iris	IRIPSE	Iridaceae		x	x	x	x
Juncus acuminatus Michx.	tapertip rush	JUNACU	Juncaceae	x	x	x	x	x
Juncus canadensis J. Gay ex Laharpe	Canadian rush	JUNCAN	Juncaceae			x		
Juncus diffusissimus Buckley	slimpod rush	JUNDIF	Juncaceae		x			
Juncus effusus L.	common rush	JUNEFF	Juncaceae	x	x	x	x	x
Juncus tenuis Willd.	poverty rush	JUNTEN	Juncaceae		x	x	x	x
Kyllinga brevifolia Rottb.	shortleaf spikesedge	KYLBRE	Cyperaceae		x	x		
Lactuca sp.	lettuce	LACSP	Asteraceae		x			
Leersia oryzoides (L.) Sw.	rice cutgrass	LEEORY	Poaceae	x	x	x	x	x
Lindernia dubia (L.) Pennell	yellowseed false pimpernel	LINDUB	Scrophulariaceae	x	x	x		x
Liriodendron tulipifera L.	tuliptree	LIRTUL	Magnoliaceae		x			
Ludwigia alternifolia L.	seedbox	LUDALT	Onagraceae	x				
Ludwigia decurrens Walter	wingleaf primrose-willow	LUDDEC	Onagraceae		x			
Ludwigia palustris (L.) Elliot	marsh seedbox	LUDPAL	Onagraceae	x	x	x	x	x
Ludwigia peploides (Kunth) P.H. Raven ssp. *glabrescens (Kuntze) P.H. Raven*	floating primrose-willow	LUDPEP	Onagraceae	x	x	x	x	x
Lycopus americanus Muhl. ex W. Bartram	American water horehound	LYCAME	Lamiaceae	x	x	x	x	x
Lycopus rubellus Moench	taperleaf water horehound	LYCRUB	Lamiaceae	x	x	x	x	x
Lycopus virginicus L.	Virginia water horehound	LYCVIR	Lamiaceae	x	x	x	x	x
Lythrum salicaria L.	purple loosestrife	LYTSAL	Lythraceae	x	x	x	x	x
Mentha arvensis L.	wild mint	MENARV	Lamiaceae		x	x	x	x
Melilotus officinalis (L.) Lam.	yellow sweet clover	MELOFF	Fabaceae		x	x		
Mikania scandens (L.) Willd.	climbing hempvine	MIKSCA	Asteraceae	x	x	x	x	x
Mimulus alatus Aiton	sharpwing monkeyflower	MIMALS	Scrophulariaceae				x	x
Mimulus ringens L.	Allegeny monkeyflower	MIMRIN	Scrophulariaceae		x	x	x	x
Murdannia keisak (Hassk.) Hand.-Maz.	wartremoving herb	MURKEI	Commelinaceae			x	x	x

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	Family	Years Observed				
				2003	2004	2005	2006	2007
Myosotis laxa Lehm.	bay forget-me-not	MYOLAX	Boraginaceae			x	x	x
Nuphar lutea (L.) Sm.	yellow pond-lily	NUPLUT	Nymphaceae	x	x	x	x	x
Oenothera sp.	evening primrose	OENSP	Onagraceae			x		
Panicum dichotomiflorum Michx.	fall panicgrass	PANDIC	Poaceae	x	x			x
Paspalum dilitatum Poir.	dallisgrass	PASDIL	Poaceae	x				
Peltandra virginica (L.) Schott	green arrow arum	PELVIR	Araceae	x	x	x	x	x
Penthorum sedoides L.	ditch stonecrop	PENSED	Saxifragaceae		x	x	x	x
Phalaris arundinacea L.	reed canarygrass	PHAARU	Poaceae			x	x	x
Phragmites australis (Cav.) Trin. ex Steud.	common reed	PHRAUS	Poaceae			x	x	x
Pilea pumila (L.) A. Gray	Canadian clearweed	PILPUM	Urticaceae		x	x	x	x
Plantago major L.	common plantain	PLASP	Platanginaceae	x	x			
Pluchea odorata (L.) Cass. var. *odorata*	sweetscent	PLUODO	Asteraceae		x			
Poa pratensis L.	Kentucky bluegrass	POAPRA	Poaceae		x	x	x	
Polygonum arifolium L.	halberdleaf tearthumb	POLARI	Polygonaceae		x	x	x	x
Polygonum cespitosum Blume var. *longisetum* (Bruijn) A.N. Steward	oriental ladysthumb	POLCES	Polygonaceae	x	x	x	x	
Polygonum hydropiper L.	marshpepper knotweed	POLHYD	Polygonaceae		x	x	x	
Polygonum lapathifolium L.	curly knotweed	POLLAP	Polygonaceae	x	x			x
Polygonum pensylvanicum L.	Pennsylvania smartweed	POLPEN	Polygonaceae	x	x	x		x
Polygonum perfoliatum L.	Asiatic tearthumb	POLPER1	Polygonaceae		x		x	
Polygonum persicaria L.	spotted ladysthumb	POLPER2	Polygonaceae	x	x	x		x
Polygonum punctatum Elliot	dotted smartweed	POLPUN	Polygonaceae	x	x	x	x	x
Polygonum sagitattum L.	arrowleaf tearthumb	POLSAG	Polygonaceae	x	x	x	x	x
Pontedaria cordata L.	pickerelweed	PONCOR	Pontedariaceae	x	x	x	x	x
Populus deltoides Bartram ex Marsh.	eastern cottonwood	POPDEL	Salicaceae	x	x	x	x	x
Ranunculus sceleratus L.	cursed buttercup	RANSCE	Ranunculaceae	x	x	x	x	

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	Family	Years Observed				
				2003	2004	2005	2006	2007
Robinia pseudoacacia L.	black locust	ROBPSE	Fabaceae			x		
Rorippa palustris (L.) Besser ssp. *fernaldiana* (Butters & Abbe) Jonsell	Fernald's yellowcress	RORPAL	Brassicaceae	x	x	x		x
Rumex crispus L.	curly dock	RUMCRI	Polygonaceae		x	x	x	x
Rumex verticillatus L.	swamp dock	RUMVER	Polygonaceae			x	x	x
Sacciolepis striata (L.) Nash	American cupscale	SACSTRI	Poaceae			x		
Sagittaria calycina Engelm. var. *calycina*	hooded arrowhead	SAGCAL	Alismataceae		x			
Sagittaria latifolia Willd.	broadleaf arrowhead	SAGLAT	Alismataceae	x	x	x	x	x
Salix nigra Marsh.	black willow	SALNIG	Salicaceae	x	x	x	x	x
Saururus cernuus L.	lizard's tail	SAUCER	Saururaceae					x
Schedonorus phoenix (Scop.) Holub	tall fescue	SCHPHO	Poaceae			x	x	x
Schoenoplectus pungens (Vahl) Palla	common threesquare	SCHPUN	Cyperaceae					x
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	softstem bulrush	SCHTAB	Cyperaceae	x	x	x	x	x
Scirpus atrovirens Willd.	green bulrush	SCIATR	Cyperaceae				x	x
Scirpus cyperinus (L.) Kunth	woolgrass	SCICYP	Cyperaceae			x	x	x
Scirpus polyphyllus Vahl	leafy bulrush	SCIPOL	Cyperaceae			x		x
Scutellaria lateriflora L.	blue skullcap	SCULAT	Lamiaceae		x	x	x	x
Solanum sp.	nightshade	SOLSP	Solanaceae		x			
Solidago canadensis L.	Canada goldenrod	SOLCAN	Asteraceae		x	x	x	
Sonchus asper (L.) Hill	spiny sowthistle	SONASP	Asteraceae		x			
Sparganium eurycarpum Engelm.	broadfruit bur-reed	SPAEUR	Sparganiaceae		x	x	x	x
Stellaria sp.	starwort	STESP	Caryophyllaceae		x			
Symphyotrichum dumosum (L.) G.L. Nesom var. *dumosum*	rice button aster	SYMDUM	Asteraceae		x	x	x	x
Symphyotrichum lateriflorum (L.) A. Löve & D. Löve var. *lateriflorum*	calico aster	SYMLAT	Asteraceae			x		

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	Family	Years Observed				
				2003	2004	2005	2006	2007
Taraxacum officinale F.H. Wigg.	common dandelion	TAROFF	Asteraceae			x		
Toxicodendron radicans (L.) Kuntze	eastern poison ivy	TOXRAD	Anacardiaceae					x
Trifolium hybridum L.	alsike clover	TRIHYB	Fabaceae			x		x
Trifolium pratense L.	red clover	TRIPRA	Fabaceae			x	x	
Trifolium repens L.	white clover	TRIREP	Fabaceae	x	x	x	x	x
Typha angustifolia L.	narrowleaf cattail	TYPANG	Typhaceae	x	x	x	x	x
Typha latifolia L.	broadleaf cattail	TYPLAT	Typhaceae	x	x	x	x	x
Ulmus americanus L.	American elm	ULMALB	Ulmaceae	x	x	x	x	x
Vernonia noveboracensis (L.) Michx.	New York ironweed	VERNOV	Asteraceae					x
Veronica peregrina L.	neckweed	VERPER	Scrophulariaceae		x			
Vitis sp.	grape	VITSP	Vitaceae		x		x	x
Xanthium strumarium L.	rough cocklebur	XANSTR	Asteraceae		x	x		
Zizania aquatica L.	annual wildrice	ZIZAQU	Poaceae		x	x	x	x

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	USFWS Wetland Indicator Status[1]	Origin[2]	Life Form[3]	Duration[4]
Acer negundo L.	boxelder	ACENEG	FAC+	N	T	P
Acer rubrum L.	red maple	ACERUB	FAC	N	T	P
Acer saccharinum L.	silver maple	ACESAC	FACW	N	T	P
Alisma subcordatum Raf.	American water plantain	ALISUB	OBL	N	F/H	P
Amaranthus cannabinus (L.) Sauer	tidalmarsh amaranth	AMACAN	OBL	N	F/H	P
Ambrosia trifida L.	great ragweed	AMBTRI	FAC	N	F/H*	A
Apios americana Medik.	groundnut	APIAME	FACW	N	V, F/H	P
Artemisia annua L.	sweet sagewort	ARTANN	FACU	I	F/H	A
Arthraxon hispidus (Thunb.) Makino	small carpgrass	ARTHIS	NI	I	G	A
Bidens aristosa (Michx.) Britton	bearded beggarticks	BIDARI	FACW-	N	F/H	A, B
Bidens connata Muhl. ex Willd.	purplestem beggarticks	BIDCON	FACW+	N	F/H	A
Bidens frondosa L.	devil's beggartick	BIDFRO	FACW	N	F/H	A
Bidens laevis (L.) Britton, Sterns & Poggenb.	smooth beggartick	BIDLAE	OBL	N	F/H	A, P
Boehmeria cylindrica (L.) Sw.	smallspike false nettle	BOECYL	FACW+	N	F/H	P
Calystegia sepium (L.) R. Br.	hedge false bindweed	CALSEP	FAC-	N & I	V, F/H	P
Carex atlantica L. H. Bailey ssp. *atlantica*	prickly bog sedge	CARATL	FACW+	N	G	P
Carex conjuncta Boott	soft fox sedge	CARCON	FACW	N	G	P
Carex crinita Lam.	fringed sedge	CARCRI	OBL	N	G	P
Carex frankii Kunth	Frank's sedge	CARFRA	OBL	N	G	P
Carex laevivaginata (Kük.) Mack.	smoothsheath sedge	CARLAE	OBL	N	G	P
Carex lurida (Wahlenb.)	shallow sedge	CARLUR	OBL	N	G	P
Carex scoparia Schkuhr ex Willd.	broom sedge	CARSCO	FACW	N	G	P
Carex stipata Muhl. ex Willd.	awlfruit sedge	CARSTI	OBL	N	G	P
Carex tribuloides Wahlenb.	blunt broom sedge	CARTRI	FACW+	N	G	P
Carex vulpinoidea Michx.	fox sedge	CARVUL	OBL	N	G	P
Cephalanthus occidentalis L.	common buttonbush	CEPOCC	OBL	N	S*	P

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	USFWS Wetland Indicator Status[1]	Origin[2]	Life Form[3]	Duration[4]
Chenopodium leptophyllum (Moq.) Nutt. ex S. Watson	narrowleaf goosefoot	CHELEP	FAC	N	F/H	A
Cicuta maculata L.	spotted water hemlock	CICMAC	OBL	N	F/H	B, P
Clematis terniflora DC.	sweet autumn virginsbower	CLETER	FACU-	I	V	P
Commelina virginica L.	Virginia dayflower	COMVIR	FACW	N	F/H	P
Conoclinium coelestinum (L.) DC.	blue mistflower	CONCOE	FAC	N	F/H	P
Conyza canadensis (L.) Cronquist var. *canadensis*	Canadian horseweed	CONCAN	UPL	N	F/H	A*
Cuscuta gronovii Willd. ex Schult.	scaldweed	CUSGRO	---	N	V, F/H	P
Cyperus erythrorhizos Muhl.	redroot flatsedge	CYPERY	FACW+	N	G	A*
Cyperus flavescens L.	yellow flatsedge	CYPFLA	OBL	N	G	A
Cyperus odoratus L.	fragrant flatsedge	CYPODO	FACW	N	G	A*
Cyperus strigosus L.	strawcolored flatsedge	CYPSTR	FACW	N	G	P
Digitaria sanguinalis (L.) Scop.	hairy crabgrass	DIGSAN	FACU-	N	G	A
Echinochloa crus-galli (L.) P. Beauv.	barnyardgrass	ECHCRU	FACU	I	G	A
Echinochloa walteri (Pursh) A. Heller	coast cockspur grass	ECHWAL	FACW+	N	G	A
Eclipta prostrata (L.) L.	false daisy	ECLPRO	FAC	N	F/H	A*
Eleocharis obtusa (Willd.) Schult.	blunt spikerush	ELEOBT	OBL	N	G	A*
Eleusine indica (L.) Gaertn.	Indian goosegrass	ELEIND	FACU-	I	G	A
Elymus virginicus L.	Virginia wildrye	ELYVIR	FACW-	N	G	P
Epilobium coloratum Biehler	purpleleaf willowherb	EPICOL	OBL	N	F/H	P
Eragrostis sp. Von Wolf	lovegrass	ERASP	---	---	G	---
Erechtites hieracifolia (L.) Raf. ex DC var. *hieracifolia*	American burnweed	EREHIE	FACU	N	F/H	A
Eupatoriadelphus fistulosus (Barratt) King & H. Rob.	trumpetweed	EUPFIS	FACW	N	F/H	P
Eupatorium serotinum Michx.	lateflowering boneset	EUPSER	FAC-	N	F/H	P
Euthamia graminifolia (L.) Nutt.	flat-top goldentop	EUTGRA	FAC	N	F/H	P
Fraxinus pennsylvanica Marsh.	green ash	FRAPEN	FACW	N	T	P
Galium tinctorium (L.) Scop.	stiff marsh bedstraw	GALTIN	OBL	N	F/H	P

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	USFWS Wetland Indicator Status[1]	Origin[2]	Life Form[3]	Duration[4]
Helenium autumnale L.	common sneezeweed	HELAUT	FACW+	N	F/H	P
Hibiscus moscheutos L.	crimsoneyed rosemallow	HIBMOS	OBL	N	F/H*	P*
Impatiens capensis Meerb.	jewelweed	IMPCAP	FACW	N	F/H	A
Iris pseudacorus L.	paleyellow iris	IRIPSE	OBL	I	F/H	P
Juncus acuminatus Michx.	tapertip rush	JUNACU	OBL	N	G	P
Juncus canadensis J. Gay ex Laharpe	Canadian rush	JUNCAN	OBL	N	G	P
Juncus diffusissimus Buckley	slimpod rush	JUNDIF	FACW	N	G	P
Juncus effusus L.	common rush	JUNEFF	FACW+	N	G	P
Juncus tenuis Willd.	poverty rush	JUNTEN	FAC-	N	G	P
Kyllinga brevifolia Rottb.	shortleaf spikesedge	KYLBRE	FACW	N	G	P
Lactuca sp L..	lettuce	LACSP	---	---	F/H	---
Leersia oryzoides (L.) Sw.	rice cutgrass	LEEORY	OBL	N	F/H	P
Lindernia dubia (L.) Pennell	yellowseed false pimpernel	LINDUB	OBL	N	F/H	A, B
Liriodendron tulipifera L.	tuliptree	LIRTUL	FACU	N	T	P
Ludwigia alternifolia L.	seedbox	LUDALT	FACW+	N	F/H	P
Ludwigia decurrens Walter	wingleaf primrose-willow	LUDDEC	OBL	N	F/H	A*
Ludwigia palustris (L.) Elliot	marsh seedbox	LUDPAL	OBL	N	F/H	P
Ludwigia peploides (Kunth) P.H. Raven ssp. *glabrescens (Kuntze) P.H. Raven*	floating primrose-willow	LUDPEP	OBL	N	F/H	P
Lycopus americanus Muhl. ex W. Bartram	American water horehound	LYCAME	OBL	N	F/H	P
Lycopus rubellus Moench	taperleaf water horehound	LYCRUB	OBL	N	F/H	P
Lycopus virginicus L.	Virginia water horehound	LYCVIR	OBL	N	F/H	P
Lythrum salicaria L.	purple loosestrife	LYTSAL	FACW+	I	F/H*	P
Mentha arvensis L.	wild mint	MENARV	FACW	N	F/H	P
Melilotus officinalis (L.) Lam.	yellow sweet clover	MELOFF	FACU-	I	F/H	A,B*

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	USFWS Wetland Indicator Status[1]	Origin[2]	Life Form[3]	Duration[4]
Mikania scandens (L.) Willd.	climbing hempvine	MIKSCA	FACW+	N	V, F/H	P
Mimulus alatus Aiton	sharpwing monkeyflower	MIMALS	OBL	N	F/H	P
Mimulus ringens L.	Allegeny monkeyflower	MIMRIN	OBL	N	F/H	P
Murdannia keisak (Hassk.) Hand.-Maz.	wartremoving herb	MURKEI	OBL	I	F/H	P
Myosotis laxa Lehm.	bay forget-me-not	MYOLAX	OBL	N	F/H	P*
Nuphar lutea (L.) Sm.	yellow pond-lily	NUPLUT	OBL	N	F/H	P
Oenothera sp L..	evening primrose	OENSP	---	---	F/H	---
Panicum dichotomiflorum Michx.	fall panicgrass	PANDIC	FACW-	N	G	A
Paspalum dilitatum Poir.	dallisgrass	PASDIL	FAC+	I	G	P
Peltandra virginica (L.) Schott	green arrow arum	PELVIR	OBL	N	F/H	P
Penthorum sedoides L.	ditch stonecrop	PENSED	OBL	N	F/H	P
Phalaris arundinacea L.	reed canarygrass	PHAARU	FACW+	N	G	P
Phragmites australis (Cav.) Trin. ex Steud.	common reed	PHRAUS	FACW	I**	G*	P
Pilea pumila (L.) A. Gray	Canadian clearweed	PILPUM	FACW	N	F/H	A
Plantago major L.	common plantain	PLASP	FACU	I	F/H	P
Pluchea odorata (L.) Cass. var. *odorata*	sweetscent	PLUODO	OBL	N	F/H	A*
Poa pratensis L.	Kentucky bluegrass	POAPRA	FACU	I*	G	P
Polygonum arifolium L.	halberdleaf tearthumb	POLARI	OBL	N	V, F/H*	A
Polygonum cespitosum Blume var. *longisetum* (Bruijn) A.N. Steward	oriental ladysthumb	POLCES	---	I	F/H	A
Polygonum hydropiper L.	marshpepper knotweed	POLHYD	OBL	I	F/H	A
Polygonum lapathifolium L.	curly knotweed	POLLAP	FACW+	N	F/H	A
Polygonum pensylvanicum L.	Pennsylvania smartweed	POLPEN	FACW	N	F/H	A
Polygonum perfoliatum L.	Asiatic tearthumb	POLPER1	FAC	I	F/H	A
Polygonum persicaria L.	spotted ladysthumb	POLPER2	FACW	I	F/H	A*
Polygonum punctatum Elliot	dotted smartweed	POLPUN	OBL	N	F/H	A, P

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	USFWS Wetland Indicator Status[1]	Origin[2]	Life Form[3]	Duration[4]
Polygonum sagitattum L.	arrowleaf tearthumb	POLSAG	OBL	N	V, F/H*	A, P
Pontedaria cordata L.	pickerelweed	PONCOR	OBL	N	F/H	P
Populus deltoides Bartram ex Marsh.	eastern cottonwood	POPDEL	FAC	N	T	P
Ranunculus sceleratus L.	cursed buttercup	RANSCE	OBL	N	F/H	A*
Robinia pseudoacacia L.	black locust	ROBPSE	FACU-	N	T	P
Rorippa palustris (L.) Besser ssp. *fernaldiana* (Butters & Abbe) Jonsell	Fernald's yellowcress	RORPAL	OBL	N	F/H	A, B*
Rumex crispus L.	curly dock	RUMCRI	FACU	I	F/H	P
Rumex verticillatus L.	swamp dock	RUMVER	OBL	N	F/H	P
Sacciolepis striata (L.) Nash	American cupscale	SACSTRI	OBL	N	G	P
Sagittaria calycina Engelm. var. *calycina*	hooded arrowhead	SAGCAL	OBL	N	F/H	P
Sagittaria latifolia Willd.	broadleaf arrowhead	SAGLAT	OBL	N	F/H	P
Salix nigra Marsh.	black willow	SALNIG	FACW+	N	T	P
Saururus cernuus L.	lizard's tail	SAUCER	OBL	N	F/H	P
Schedonorus phoenix (Scop.) Holub	tall fescue	SCHPHO	FACU	I	G	P
Schoenoplectus pungens (Vahl) Palla	common threesquare	SCHPUN	FACW+	N	G	P
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	softstem bulrush	SCHTAB	OBL	N	G	P
Scirpus atrovirens Willd.	green bulrush	SCIATR	OBL	N	G	P
Scirpus cyperinus (L.) Kunth	woolgrass	SCICYP	FACW+	N	G	P
Scirpus polyphyllus Vahl	leafy bulrush	SCIPOL	OBL	N	G	P
Scutellaria lateriflora L.	blue skullcap	SCULAT	FACW+	N	F/H	P
Solanum sp. L.	nightshade	SOLSP	---	---	F/H	---
Solidago canadensis L.	Canada goldenrod	SOLCAN	FACU	N	F/H	P
Sonchus asper (L.) Hill	spiny sowthistle	SONASP	FAC	I	F/H	A
Sparganium eurycarpum Engelm.	broadfruit bur-reed	SPAEUR	OBL	N	F/H	P
Stellaria L.	starwort	STESP			F/H	

Appendix (Cont.). Anacostia River Fringe Wetlands Restoration Project list of species observed 2003 through 2007. The list represents a compilation of species observed within and outside the plots during the quantitative sampling events as well as during additional walk throughs. Classifications are from the PLANTS database (USDA, NRCS 2008). *indicates a modification based on local information provided in Brown and Brown (1984).

Species	Common Name	Acronym	USFWS Wetland Indicator Status[1]	Origin[2]	Life Form[3]	Duration[4]
Symphyotrichum dumosum (L.) G.L. Nesom var. *dumosum*	rice button aster	SYMDUM	FAC	N	F/H	P
Symphyotrichum lateriflorum (L.) A. Löve & D. Löve var. *lateriflorum*	calico aster	SYMLAT	FACW-	N	F/H	P
Taraxacum officinale F.H. Wigg.	common dandelion	TAROFF	FACU-	I	F/H	P
Toxicodendron radicans (L.) Kuntze	eastern poison ivy	TOXRAD	FAC	N	S, SS, V	P
Trifolium hybridum L.	alsike clover	TRIHYB	FACU-	I	F/H	P*
Trifolium pratense L.	red clover	TRIPRA	FACU-	I	F/H	P, B
Trifolium repens L.	white clover	TRIREP	FACU-	I	F/H	P
Typha angustifolia L.	narrowleaf cattail	TYPANG	OBL	I	G	P
Typha latifolia L.	broadleaf cattail	TYPLAT	OBL	N	G	P
Ulmus americanus L.	American elm	ULMALB	FACW-	N	T	P
Vernonia noveboracensis (L.) Michx.	New York ironweed	VERNOV	FACW+	N	F/H	P
Veronica peregrina L.	neckweed	VERPER	FACU-	N	F/H	A
Vitis sp. L.	grape	VITSP	---		V	P
Xanthium strumarium L.	rough cocklebur	XANSTR	FAC	N	F/H	A
Zizania aquatica L.	annual wildrice	ZIZAQU	OBL	N	G	A

[1] USFWS Wetland Indicator Status reported is that for Region 1 taken from PLANTS (USDA, NRCS 2008).

Data and definitions in the PLANTS wetland reports are abstracted from:

U.S. Fish and Wildlife Service. 1988. *National list of vascular plant species that occur in wetlands.* U.S. Fish & Wildlife Service Biological Report 88 (26.9).

U.S. Fish and Wildlife Service. 1993. *1993 supplement to list of plant species that occur in wetlands: Northwest (Region 9).* Supplement to U.S. Fish & Wildlife Service Biological Report 88 (26.9).

Indicator categories

Indicator Code	Wetland Type	Comment
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
NI	No indicator	Insufficient information was available to determine an indicator status.

National Indicators reflect the range of estimated probabilities (expressed as a frequency of occurrence) of a species occurring in wetlands versus non-wetland across the entire distribution of the species. A frequency, for example, of 67%-99% (Facultative Wetland) means that 67%-99% of sample plots containing the species randomly selected across the range of the species would be wetland. When two indicators are given, they reflect the range from the lowest to the highest frequency of occurrence in wetlands across the regions in which the species is found. A positive (+) or negative (-) sign was used with the Facultative Indicator categories to more specifically define the regional frequency of occurrence in wetlands. The positive sign indicates a frequency toward the higher end of the category (more frequently found in wetlands), and a negative sign indicates a frequency toward the lower end of the category (less frequently found in wetlands).

Regional Indicators express the estimated probability (likelihood) of a species occurring in wetlands versus non-wetlands in the region. Regional Indicators reflect the unanimous agreement of the Regional Interagency Review Panel.

[2] Origin classification is taken from PLANTS (USDA, NRCS 2008): N = Native, I = Introduced (Exotic).

[3] Life form classification is taken from PLANTS (USDA, NRCS 2008): F/H= forb/herb, G = graminoid, S = shrub, SS = subshrub, T = tree, V = vine.

[4] Duration classification is taken from PLANTS (USDA, NRCS 2008): A = annual, B = biennial, P = perennial. *indicates a modification based on local information provided in Brown and Brown (1984).