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Primary Succession in a Created Freshwater Wetland

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ABSTRACT

Plant cover, density, and standing crop biomass were measured and compared in a created wetland and an adjacent freshwater marsh (reference wetland) in Charles City County, Virginia. No significant difference was observed between monthly standing crop in the created wetland and the reference wetland. Species composition differed between sites (mean SI < 0.50) with no significant relationship between species composition and distance from adjacent seed source. Dominant species in created wetland (*Eleocharis obtusa*, *Juncus acuminatus*) were dissimilar to those of the reference wetland (*Dichanthelium dichotomum* var. *dichotomum*, *Scirpus cyperinus*). Results suggest that if both standing crop and composition are going to be used to establish short-term goals for a created wetland, these two measures should not be considered interdependent. Further, the high relative importance of perennials within the created wetland does not fit primary succession predictions, indicating that certain wetland perennials utilize "annual" strategies when substrates are available. Management alternatives should accommodate establishment of these species, which are important in early successional development of created wetland sites.

INTRODUCTION

Wetland creation attempts are often initiated by the removal of upland surface soil materials exposing mineral subsoil strata (Atkinson et al. 1993). The extent to which the revegetation sequence may be viewed as primary succession is dependent upon the amount of soil removal and the viability of the pre-existing seed bank (Mitsch and Gosselink 2000). The presence of wetland species in the seed bank following construction will often be minimal or lacking based on the antecedent upland condition of the site (Kusler and Kentula 1989). Species present during the first few years of vegetation establishment that were not planted or seeded are assumed to be volunteers from offsite sources (Reinhartz and Warne 1993), and therefore represent the primary seral stage of vegetation succession. For the purposes of this review, we define "created wetland" in the context of wetland regulation in the United States as the "establishment of a wetland . . . where one did not formerly exist" (Federal Register Vol. 60, No. 228, p. 58613).

Created wetland sites located in close proximity to undisturbed, adjacent wetlands have shown greater colonization of wetland species than more remote sites (Brown 1998, Brown and Bedford 1997, Reinhartz and Warne 1993). In these systems, vegetation in adjacent wetlands may be a potential seed source, particularly from habitats dominated by herbaceous species that are more likely to colonize a young substrate (Thompson 1992).

Prediction of pioneering species composition can be based on a working knowledge of the life history strategies and reproductive phenologies of the volunteer vegetation (ter Heerdt and Drost 1994, van der Valk 1981). Classifying species according to life history (i.e., annual vs. perennial) on created wetland sites may help describe vegetation recruitment patterns in the context of existing wetland succession models (van der Valk 1981, Mitsch and Gosselink 2000).

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The purpose of this study was to compare vegetative species composition and standing crop in a newly created freshwater wetland with that of an adjacent freshwater emergent reference wetland. From this information, we will determine the types of species that utilize created wetland sites as colonizing substrates, and evaluate composition, standing crop, and distance from a seed source as indicators of wetland vegetation establishment in young sites.

METHODS

Site Description

The study site is a created wetland in Charles City County, Virginia, located on a tributary of the Chickahominy River in the James River watershed (37°20′58″ Lat., 76°55′30″ Long.; Figure 1). The area was designed for use as forested wetland mitigation, and construction was completed in mid-summer 1996. The sampling window (April to August, 1998) represents the second full growing season following final grading on the site. Woody species had not been planted at the time of the study.

The sample site included a portion of the created wetland and a recently timbered (1996) secondary successional emergent reference wetland that was adjacent to the created wetland. The two sites were approximately 10 meters apart, and were separated by a broad, flat, shallow upland berm (ca. two feet high) which prevented the direct flow of surface water between the sites (Figure 2). The upland berm was created as a construction access road in 1996, and during this study (1998) was populated with native scrub vegetation.

Both sites (created wetland and reference wetland) may be classified as palustrine emergent headwater wetlands (Cowardin et al. 1979). The reference wetland lay adjacent to a larger forested wetland complex to the east (Figure 2). Principle hydrology sources for the two sites included precipitation capture and runoff from adjacent forested areas. No soil amendments were incorporated into the created wetland during construction, and the site had been seeded with a stabilizing grass seed mix of *Lolium perenne* ssp. *multiflorum* and *Panicum virgatum* immediately after grading was completed. During the study (April–August 1998), both sites were inundated with shallow surface water (ca. 5–12 cm) through June.

Study Design

A baseline was established perpendicular to the created wetland/reference wetland interface, from which sampling transects were placed at 2 m, 20 m, 40 m, 60 m, and 80 m parallel to the edge of the created wetland. The use of a stratified random sampling design allowed analysis of distance from the potential seed source (reference wetland) as an independent variable of vegetation establishment. In the reference wetland, a random sampling design was employed in which a single baseline was determined and three random transects were established perpendicular from that baseline. Transect position and plot distance along each transect varied from month to month to accommodate destructive sampling (standing crop). The adequacy of the sample size in the reference wetland was verified by species-area curves at the outset of the study (Mueller-Dombois and Ellenburg 1974). Three random points were established on each of the five created wetland transects and the three reference wetland transects monthly (mid-month), April through August, 1998, for a total of 75 points in the created wetland and 15 points in the reference wetland over the five month study period.

$1 \text{ m} \times 1 \text{ m}$ PVC quadrats were used to demarcate plots at each random point. Percent cover was estimated from each plot for each species present using a modified Braun-Blanquet cover scale (Daubenmire 1959), where data were recorded as mid-points of the cover ranges (mid-points in parentheses): (95–100% (97.5%), 75–95% (85%), 50–75% (62.5%), 25–50% (37.5%), 5–25% (15%), 1–5% (3%), <1% (0.5%). Plots were marked in the field and re-visited for proper identification of seedlings and immature specimens.

Density counts by species were made from 1/4 m^2 ($50 \text{ cm} \times 50 \text{ cm}$ PVC frame) randomly located in one corner of each plot. For cespitose species, an individual was defined as all identifiable aboveground vegetation generated from the same rootstock (genet), generally determined by inspection of the plant at soil level. For rhizomatous species, individual stems

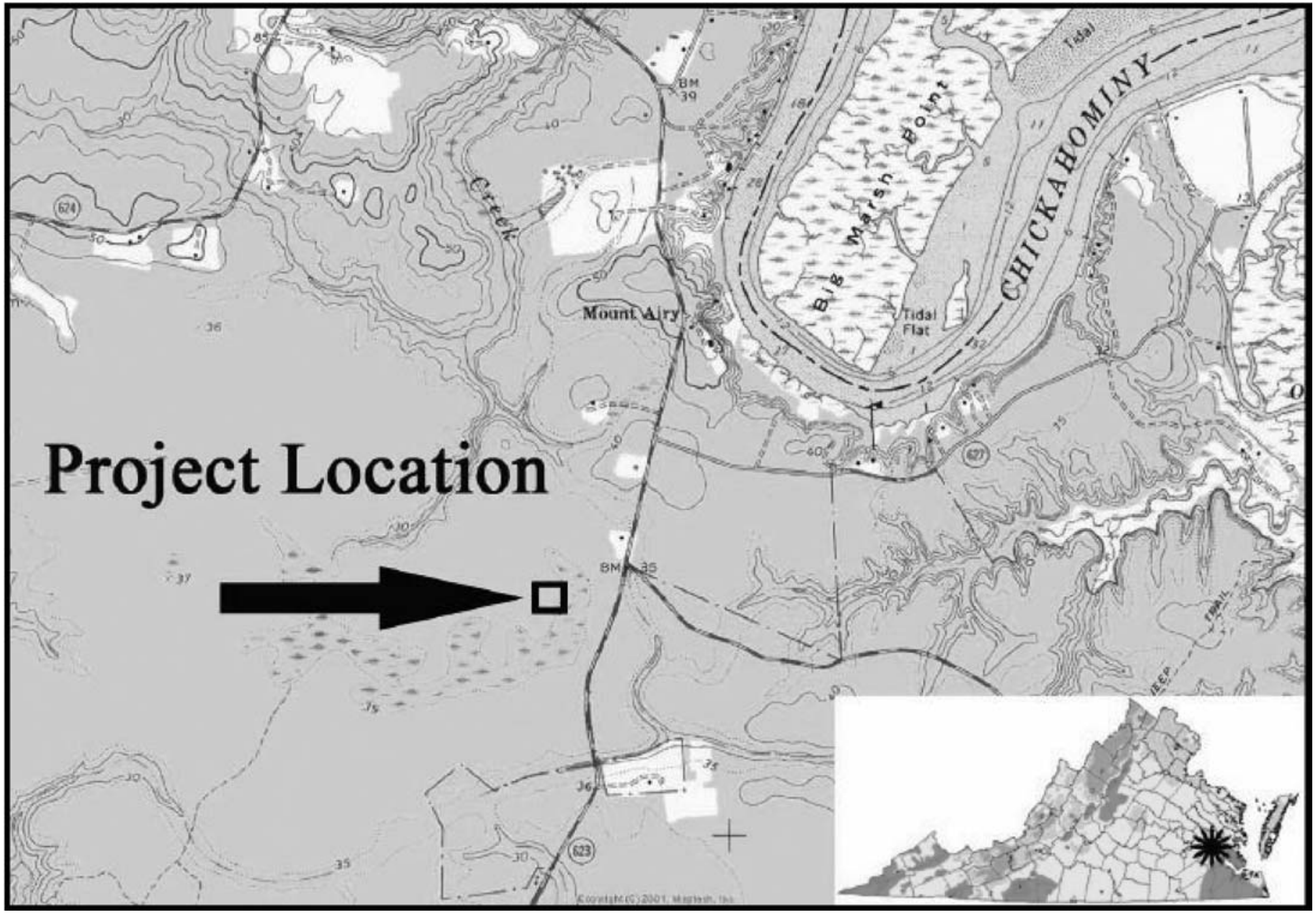

Figure 1. Location of the Charles City County non-tidal wetland mitigation area. Source: USGS 7.5 Minute Series Topographic Map, Brandon, Virginia Quadrangle, 1965 (Revised 1980).

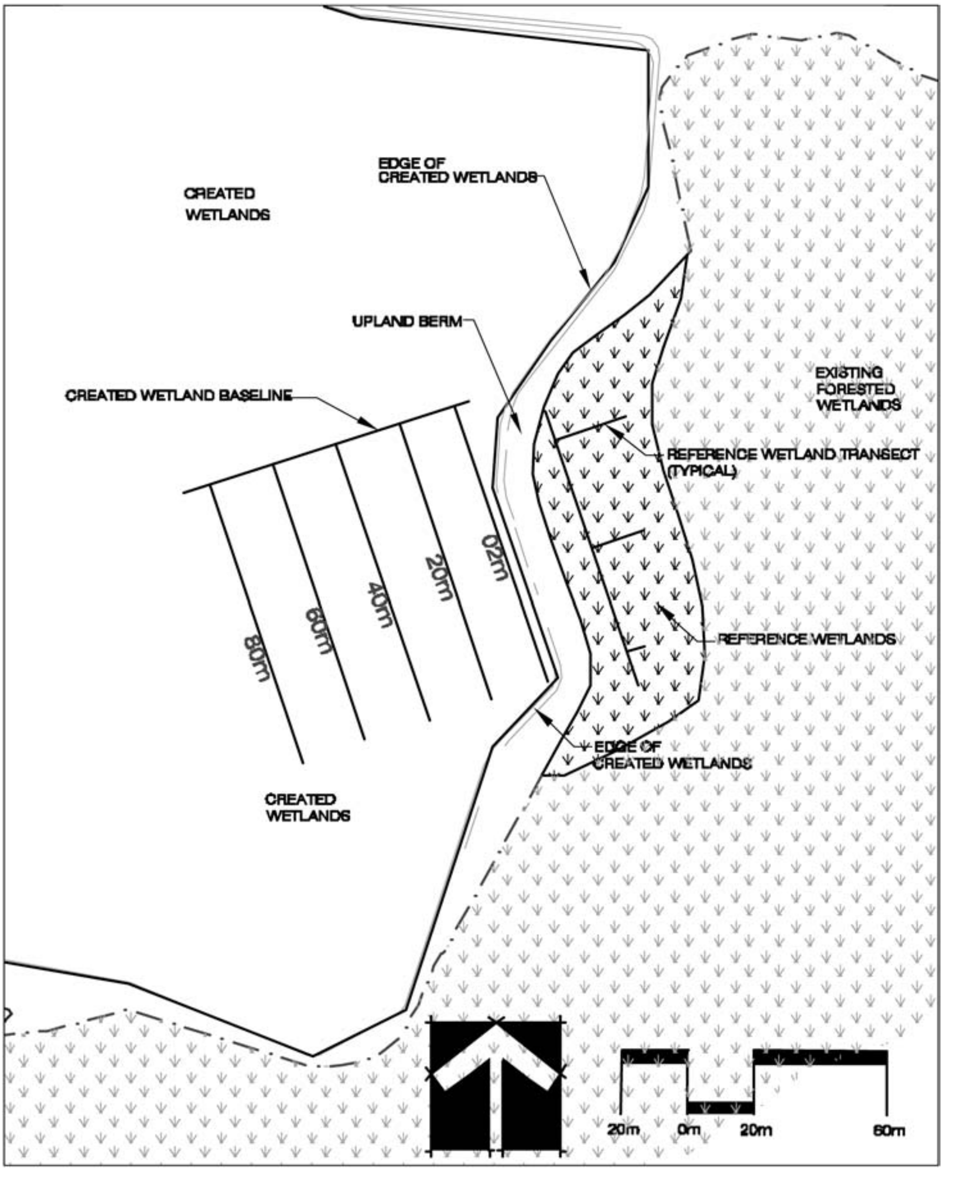

Figure 2. Sample design.

(ramets) were counted as separate plants. The 1/4 m^2 density measures were then transformed to 1 m^2 for analysis.

Aboveground standing crop (SC) was harvested by clipping all living and standing dead biomass at the soil surface from one 1/8 m^2 plot (25 cm × 50 cm PVC frame). An SC subsample was taken from randomly determined corners of the cover plot on each transect. Harvested plant material was dried at a constant temperature (40°C) for a minimum of five days until constant mass was achieved.

Plant taxonomy follows Gleason and Cronquist (1991) and nomenclature follows Kartesz (1994). Determination of annual vs. perennial status was based upon life history traits according to Gleason and Cronquist (1991), Godfrey and Wooten (1979a, 1979b), and Radford et al. (1968).

Data Analysis

Cover, density, and frequency were converted to relative measures (Causton 1988), and Importance Values (IV) were then calculated as the sum of relative dominance, relative density, and relative frequency for each species (Perry and Atkinson 1997). Dominant species were selected by ranking in order of descending IV, with dominants comprising the first 50% of the total IV and any additional species greater than 20% (50:20 rule). Species composition was compared between the created wetland and reference wetland by calculation of a Sørensen Similarity Index (SI) (Mueller-Dombois and Ellenburg 1974). SC comparisons between the created wetland and reference wetland were made with Repeated Measure Analysis of Variance with time (collecting date) as a control. All statistics were performed on StatMost for Windows software (DataMost 1994).

RESULTS

Fifty-one (51) species were identified from 90 sample plots (created wetland and reference wetland combined) during the five sampling events in mid-April through mid-August 1998 (Table 1). Voucher specimens were deposited in the College of William and Mary Herbarium (WILLI). Of the species present, 20 were found exclusively in the created wetland, 18 were common to both the created wetland and reference wetland, and 13 were sampled in the reference wetland only.

Two dominant species were present in the created wetland, including *Eleocharis obtusa* (IV: 33.4) and *Juncus acuminatus* (IV: 29.6). In addition, two dominants occurred in the reference wetland, including *Dichanthelium dichotomum* var. *dichotomum* (IV: 32.0) and *Scirpus cyperinus* (IV: 26.7). *Juncus acuminatus*, although not dominant, was also common in the reference wetland (IV: 8.9). In the created wetland, *Lolium perenne* ssp. *multiflorum* (IV: 8.5) and *Panicum virgatum* (IV: 3.5), which had been included in a stabilizing seed mix that was applied to the site following construction, were among the more common graminoids identified.

Sørensen Similarity Indices (SI) were high among transects within the created wetland (>0.50), but low between the created wetland and reference wetland (<0.50) (Table 2). The 95% confidence interval for SI values from the reference wetland-created wetland pairings showed that the difference between indices was not significant, indicating a lack of correlation between distance from the seed source (reference wetland) and species affinity. Therefore, nearby transects were no more similar in species composition to the reference wetland than transects farther away.

A cumulative IV total for the created wetland indicated that annuals contributed 49.1% to the vegetative cover, and perennials and/or facultative annuals (i.e., plants that exploit both annual and perennial life history) comprised 39.5% by comparison (excluding planted species). In the reference wetland, annuals and perennials contributed 3.7% and 96.3%, respectively.

The highest standing crop (SC) values were sampled from the 20 m transect in the created wetland in August (896.0 g/m^2), and the lowest from the 40 m transect in April (29.6 g/m^2) (Table 3). One-way ANOVA results for SC showed no significant differences between values in the reference wetland and each of the created wetland transects (Table 4).

DISCUSSION

The lack of correlation between distance from the potential seed source (reference wetland) and compositional variability in the created wetland disagrees with other studies in created wetlands (Reinhartz and Warne 1993). Our results may be explained by the different successional stages of the two systems. The created wetland was in a primary seral stage at the time of this investigation. Following construction, the substrate in the created wetland was composed of unamended mineral subsoil material, presumably devoid of viable seeds. Although the site was seeded with a stabilizing grass seed mix, only two species were included in the mix (*Lolium perenne* ssp. *multiflorum, Panicum virgatum*), and neither was a dominant. All other species appearing in the created wetland during this study were assumed to have volunteered from off-site sources (i.e., primary succession). Conversely, timbering of the slightly older

Table 1. Importance values (IV) and life history duration (annual vs. perennial) for all species identified in the created wetland (CW) and the reference wetland (RW). IV's were calculated for each sampling event (i.e., monthly) and averaged over the growing season to produce a single IV for each species present at each site. A = annual species, P = perennial species, A/P = species displays both annual and perennial duration

Species	CW IV	RW IV	A/P
Aceraceae			
Acer rubrum L. (red maple)	0.0	0.1	P
Anacardiaceae			
Toxicodendron radicans (L.) Kuntze (eastern poison ivy)		0.5	P
Asteraceae			
Antennaria plantaginifolia (L.) Richards (woman's tobacco)		0.0	P
Bidens frondosa L. (devil's beggartick)	1.6		A
Eupatorium fistulosum Barratt (trumpetweed)		0.1	P
Euthamia graminifolia (L.) Nutt. (flattop goldenrod)	0.4	2.6	P
Mikania scandens (L.) Willd. (climbing hempvine)	0.0	0.3	P
Pluchea camphorata (L.) DC. (camphor pluchea)		0.0	A/P
Clethraceae			
Clethra alnifolia L. (sweetpepperbush)		0.0	P
Clusiaceae			
Hypericum hypericoides (L.) Crantz (St. Andrews cross)		0.0	P
Hypericum mutilum L. (dwarf St. Johnswort)	0.0	0.2	A/P
Cyperaceae			
Carex complanata Torr. & Hook. (blue sedge)		1.5	P
Carex festucacea Schkuhr ex Willd. (fescue sedge)		0.8	P
Cyperus pseudovegetus Steud. (marsh flatsedge)	0.3	0.3	P
Cyperus strigosus L. (strawcolor flatsedge)	0.0		P
Eleocharis obtusa (Willd.) J.A. Schultes (blunt spikerush)	33.4		A
Eleocharis tenuis (Willd.) J.A. Schultes (slender spikerush)	0.4	0.0	P
Frimbristylis autumnalis (L.) Roemer & J.A. Schultes (slender fimbry)	0.0		A
Rhynchospora corniculata (Lam.) Gray (horned beaksedge)	0.2		P
Scirpus cyperinus (L.) Kunth (woolgrass)	1.2	26.7	P
Ericaceae			
Vaccinium corymbosum L. (highbush blueberry)		0.0	P
Euphorbiaceae			
Chamaesyce maculata (L.) Small (spotted sandmat)	0.0		A
Phyllanthus caroliniensis Walt. (Carolina leafflower)	0.0		A
Fabaceae			
Lespedeza procumbens Michx. (trailing lespedeza)	0.0		P
Juncaceae			
Juncus acuminatus Michx. (tapertip rush)	29.6	8.9	P
Juncus effusus L. (common rush)	1.2	5.1	P
Juncus scirpoides Lam. (needlepod rush)	0.7		P
Juncus tenuis Willd. (poverty rush)	0.1	0.8	P
Melastomataceae			
Rhexia mariana L. (Maryland meadowbeauty)	0.0	1.4	P
Nyssaceae			
Nyssa sylvatica Marsh. (black gum)		0.3	P

Table 1. Continued

Species	CW IV	RW IV	A/P
Onagraceae			
Ludwigia alternifolia L. (seedbox)	1.3	4.7	P
Ludwigia glandulosa Walt. (primrose willow)	0.2	0.0	P
Ludwigia palustris (L.) Ell. (marsh seedbox)	2.4	1.9	P
Poaceae			
Andropogon virginicus L. (broomsedge)	0.1	0.5	P
Chasmanthium laxum (L.) Yates (slender woodoats)		0.0	P
Dichanthelium dichotomum var. *dichotomum* (L.) Gould (cypress panicgrass)	0.3	32.0	P
Dichanthelium oligosanthes var. *scribnerianum* (Nash) Gould (Scribner's rosette grass)	0.6		P
Digitaria ischaemum (Schreb.) Muhl. (smooth crabgrass)	4.7		A
Echinochloa muricata (Beauv.) Fern. (rough barnyardgrass)	1.2		A
Lolium perenne ssp. *multiflorum* (Lam.) Husnot (Italian ryegrass)	8.5		A/P
Panicum dichotomiflorum Michx. (fall panicgrass)	7.5		A
Panicum verrucosum Muhl. (warty panicgrass)	0.1	3.4	A
Panicum virgatum L. (switchgrass)	3.5		P
Paspalum laeve Michx. (field paspalum)	0.0		P
Polygonaceae			
Polygonum hydropiperoides Michx. (swamp smartweed)	0.5		P
Polygonum persicaria L. (spotted ladysthumb)	0.1		A/P
Rosaceae			
Rubus argutus Link (sawtooth blackberry)		1.6	P
Scrophulariaceae			
Agalinis purpurea (L.) Pennell (purple false foxglove)	0.1		A
Gratiola neglecta Torr. (clammy hedgehyssop)	0.1		A
Lindernia dubia var. *anagallidea* (Michx.) Cooperrider (yellowseed false pimpernel)	0.5	0.2	A
Smilacaceae			
Smilax rotundifolia L. (roundleaf greenbriar)		4.7	P

reference wetland (1996) left the seed bank somewhat intact (i.e., secondary succession). The difference in age and, presumably, species composition of the two seed banks is reflected in the low similarity between the two sites.

The establishment of volunteer species at this site does not follow the typical model of primary succession, which would predict an overall dominance of annual species with an exploitative advantage in disturbed, uncolonized habitats (van der Valk 1981, Thompson 1992). Although annuals represented a greater proportion of the IV for the created site, perennials and

Table 2. Sørensen Similarity Index (SI) matrix (2c/a + b). Similarity was low between the reference wetland (RW) and all transects within the created wetland (i.e., SI < 0.50). Values for RW indices are contained within the 95% confidence interval (0.4607 ± 0.0387)

	RW	80 m	60 m	40 m	20 m
02 m	0.4231	0.6729	0.7805	0.8085	0.7727
20 m	0.4815	0.6909	0.7907	0.7347	
40 m	0.4912	0.7931	0.7826		
60 m	0.4313	0.7308			
80 m	0.4762				

Table 3. **Seasonal standing crop (SC) data (g/m²). Created wetland = CW, reference wetland = RW, 20 m = 20 m transect, etc.**

	April	May	June	July	August
02 m CW	35.2	71.2	245.6	254.4	353.6
20 m CW	89.6	175.2	367.2	420.8	896.0
40 m CW	29.6	125.6	192.0	184.8	215.2
60 m CW	56.0	109.6	145.6	156.8	181.6
80 m CW	45.6	220.0	140.0	195.2	145.6
RW	69.6	167.2	372.0	364.0	462.4

facultative annuals comprised nearly 40% of the cumulative total, which is much higher than succession models would predict. This introduces an interesting question: Where were the perennial seeds originating?

A common characteristic of annuals is propagule longevity, which is not typical of perennial species. However anoxic conditions in submerged substrates may extend the physiological viability of seeds (Leck 1989). Submerged habitats are commonly visited by wading birds that gather seeds on mud-encrusted feathers and legs, and can transport propagules great distances in this manner (Fenner 1985). On our site, there was no apparent surface hydrology connection to neighboring emergent wetlands, suggesting that propagules are arriving by other means. Although actual dispersal vectors were not identified in this study, we hypothesize that wildlife—particularly wading birds—may represent the primary vector for many of the perennial or facultative annuals species found (Fenner 1985, pers. obs.). If this is true, species such as *Juncus acuminatus* may be brought in from distant sources and proliferate, giving perennials an "annual" capacity to colonize new substrates. Therefore, it may be beneficial during wetland creation practices to create a seed bank of such species through seed application immediately following construction.

Our results indicate that the existing adjacent emergent wetlands may not have contributed the first colonizers to the created wetland used in this study, and that the stage of succession may have been more influential in determining initial species composition. If both vegetation composition and standing crop are going to be used to monitor success or establish short-term goals for a created wetland, they should not be considered interdependent.

CONCLUSIONS

Composition varied but standing crop did not differ between the created wetland and the reference wetland. There was no significant relationship between seed source and distance in the created wetland during the sampling period and on the spatial scale of this study. *Juncus acuminatus* and *Eleocharis obtusa* were successful colonizers and contributed to the overall structure of the created wetland. The strong presence of perennial emergents in the created wetland does not fit the typical model of primary succession (van der Valk 1981), and may indicate that perennial wetland plants exhibit "annual" strategies in exploiting recently exposed wetland substrates. It would be a beneficial wetland establishment technique to incorporate

Table 4. **One-way ANOVA for standing crop (SC) data. No significant difference was observed in standing crop values between the reference wetland (RW) and created wetland (CW) plots ($p > 0.05$)**

	F	P
RW − 02 m CW	1.072	0.3427
RW − 20 m CW	0.3841	0.5500
RW − 40 m CW	2.9616	0.1236
RW − 60 m CW	5.2915	0.0721
RW − 80 m CW	3.0735	0.1177

these native species into a planting plan for early, rapid plant establishment and site stabilization following construction on wetland creation sites in this region.

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