Soil properties of three newly created wetlands

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Introduction

Since the early 1990s, as recommended by the National Wetlands Policy Forum, a policy of "no net loss" of wetlands was put into place within many government agencies, including the Department of the Interior, the US Environmental Protection Agency, the US Army Corps of Engineers, and the Department of Agriculture (Mitsch and Gosselink, 1993). The ramifications of this adapted policy are that wetlands can continue to be destroyed as long as mitigation sites are developed to offset these losses. And, although this policy represents a major step toward short-term wetland conservation, there are still justifiable concerns for long-term wetland sustainability.

One important concept that has not been addressed within the regulation policies is the issue of net loss of wetland functions. Since wetlands are by no means homogeneous, the replacement of a natural system by a constructed one will probably not replicate all of the functions that had been performed. Also, despite the plethora of wetland research that has taken place within the last two decades, wetland processes are still poorly understood, and this is especially true for created systems. Wetland scientists have commented that little short-term monitoring and even less long-term monitoring of restored and created sites has occurred making it difficult to determine the status of these systems and success rates of mitigation sites (Kusler and Kentula, 1989; Erwin, 1989; Lowry, 1989; Denny, 1994).

The ability to create wetland systems that exist in perpetuity and perform functions for which they were intended is greatly dependent on understanding processes which occur particularly with regard to the interactions and dynamics between the hydrological components and the biotic and abiotic components. This knowledge would in turn make wetland management easier, more cost efficient, more productive, and less time consuming, and would result in higher success rates for mitigation sites.

In 1992, wetlands were created at The Ohio State University, Columbus, Ohio in order to facilitate long-term studies on created freshwater emergent marsh and riparian wetland systems. Known as the Olentangy River Wetland Research Park (ORWRP), these wetlands have been the subject of numerous studies to date dealing with all aspects of wetland functions including hydrology, vegetation dynamics, biogeochemical processes, animal use, biotic and abiotic interactions and substrate characteristics. This particular study represents a portion of the 1998 research at the site dealing with the substrate characteristics after almost five years of flooding. The aims of this research were 1) to determine soil conditions throughout the wetlands, 2) to compare these data with data of previous years, and 3) to add 1998 data to the existing database. Studies have shown that the estimates on time required to form redoximorphic features within hydric soils can vary from less than one year to more than 100 years (McCullough, 1998). As well, results of other studies examining soil development in created wetlands showed definite differences between created and natural wetland soils. Soils within created sites were found to have much lower organic matter content and show far fewer mottling and gleying characteristics (Confer and Neiring, 1992; Bishel-Machung et al., 1996; Stauffer and Brooks, 1997).

Methods

Site Description

The ORWRP is located on ten hectares of previously abandoned farm fields at the northern end of The Ohio State University Campus. It is within the Olentangy River flood plain and is underlain with 33 to 83 m of glacial outwash deposit. The soils are of the Ross and Eldean series and consist of silt loam, silt clay, and clay loams (Mitsch, 1993).

Two 1-ha emergent marsh systems known as Wetlands 1 and 2 were excavated and then flooded in March 1994 (Fig. 1). The two wetlands were designed with deeper water sections located in the north, central, and southern portions of their basins and gently sloping topography to allow gradients from deep water through transitional to upland zones. Both receive river water pumped at controlled rates from the adjacent Olentangy River. Water enters these basins at their northern end and flows southward were it exits through water level control structures located at the southern end. Wetland 1 was planted with hydrophytes while Wetland 2 was left to establish naturally. Preflood soil analysis was performed in 1992 and 1993 while post flood soil analysis took place in 1994, 1995, 1996, and 1997 (Mitsch, 1993; Nairn et al., 1994; Wang et al., 1995; Nairn and Mitsch, 1996; Ahn and Mitsch, 1997; Fineran et al., 1998). In the fall of 1996, a third 3-ha wetland site was developed as a mitigation project (Fig. 1). Called the Billabong, it is located to the east of Wetlands 1 and 2 and was designed to function as a riparian system. It is fed by river water during periods of high water levels and is also connected to a groundwater source. Typically the Billabong is wet during the winter and spring months and experiences dry periods during the summer, which is a consistent hydroperiod pattern for riparian wetland systems throughout Ohio.

Field Work

Soil samples were collected from sites throughout Wetlands 1 and 2 in areas similar to those of previous studies. Cores were obtained from the deep-water basins in both wetlands as well as from edge, transition, and upland locations. Soils cores were also obtained from the Billabong at deeper water, transition, and upland locations (Fig. 1). All cores were obtained using a 2-cm stainless steel hand-held soil probe and were analyzed in the field for texture using standard methods described in Bates et al. (1982). Color throughout the soil profile was determined by using a Munsell Color Chart. Mottles were also noted. The top 20 cm of each soil core was placed into sealed plastic bags and then refrigerated at the Wetland Ecology Laboratory until loss on ignition testing took place.

Laboratory Analysis

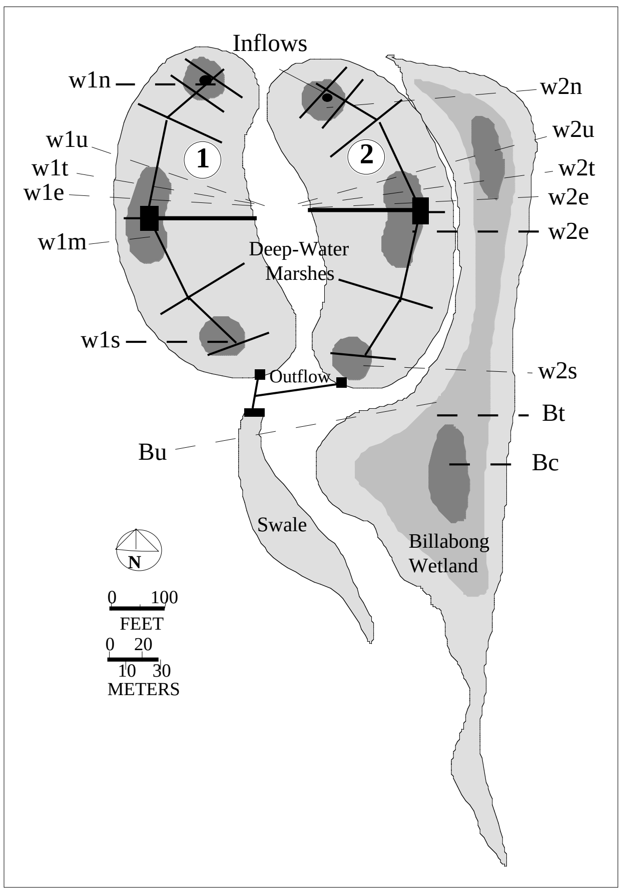

Figure 1. Soil sampling locations at the Olentangy River Wetland Research Park in 1998

Each sample core was mixed thoroughly and then a measured volume of 9 cm^3 was placed in weighed crucibles. Three samples per core were analyzed for bulk density, percent organic carbon, and percent inorganic carbon. Samples were weighed and then oven-dried at 100°C overnight. Samples were then reweighed and moisture content and bulk density were determined. After burning at 550°C in a muffle furnace for two hours, samples were weighed to determine percent organic matter. Samples were then placed in the muffle furnace and burned at 1000°C for one hour. The difference in weight between post- and pre-1000°C burning represented loss on ignition due to inorganic carbon loss, particularly carbonates (Dean, 1974).

Data Analysis

Sample data for all sites for bulk density, organic matter and carbonate were averaged and then compared using the two-tailed Students t test. This data was also statistically compared to those of previous years' studies to determine significant differences at 0.01 and 0.05 confidence levels.

Results

Examination of the soil profiles showed a markedly deeper muck layer within the three deep water basins of Wetlands 1 and 2 compared to the edge, transition, upland areas, and the Billabong (Fig. 2). Muck depth ranged from 6 to 16 cm in the deeper water sites compared to 0 to 2 cm in the edge, transition, and upland sites. The Billabong muck layer depths were 2 cm deep for both the deeper water and transition sites with no muck present in the upland profile. The color of these mucks ranged from 2.5 Y 2/0 to 2.5Y 3/2, representing dark hues and chromas consistent with those of hydric soils. Below these muck layers hue and chroma values ranged from 3/0 to 3/1 depending upon the amount of muck present within the transition zones toward the silty clays beneath. All profiles were consistent in the presence of silty clay either beginning at the surface for the upland soils, under leaf litter, or underneath the muck and transition layers within the wetland soils. Only two cores had mottles observed in the profile. These were both located in the Wetland 1 basin along the edge zone and in the deep-water area in the southern end of Wetland 1 (w1s).

The highest bulk densities were found in the soils of the deep-water sections of Wetlands 1 and 2 and ranged from 1.39 g/cm^3 to 1.68 g/cm^3 (Fig. 3). A distinct trend of higher bulk densities occurred within the deeper water basins of all three wetlands compared to edge and transition zones.

Percent organic matter ranged from 3.5% to 4.2% within the deeper water basins (Fig. 4). Slightly higher organic content was found in the soils within the edge, transition, and upland zones (4.3 to 6.3%). Billabong samples were similar regardless of their location, ranging from 3.4% to 3.9%.

Percent inorganic carbonate within the soil was be low for all samples. Two locations with the highest values were

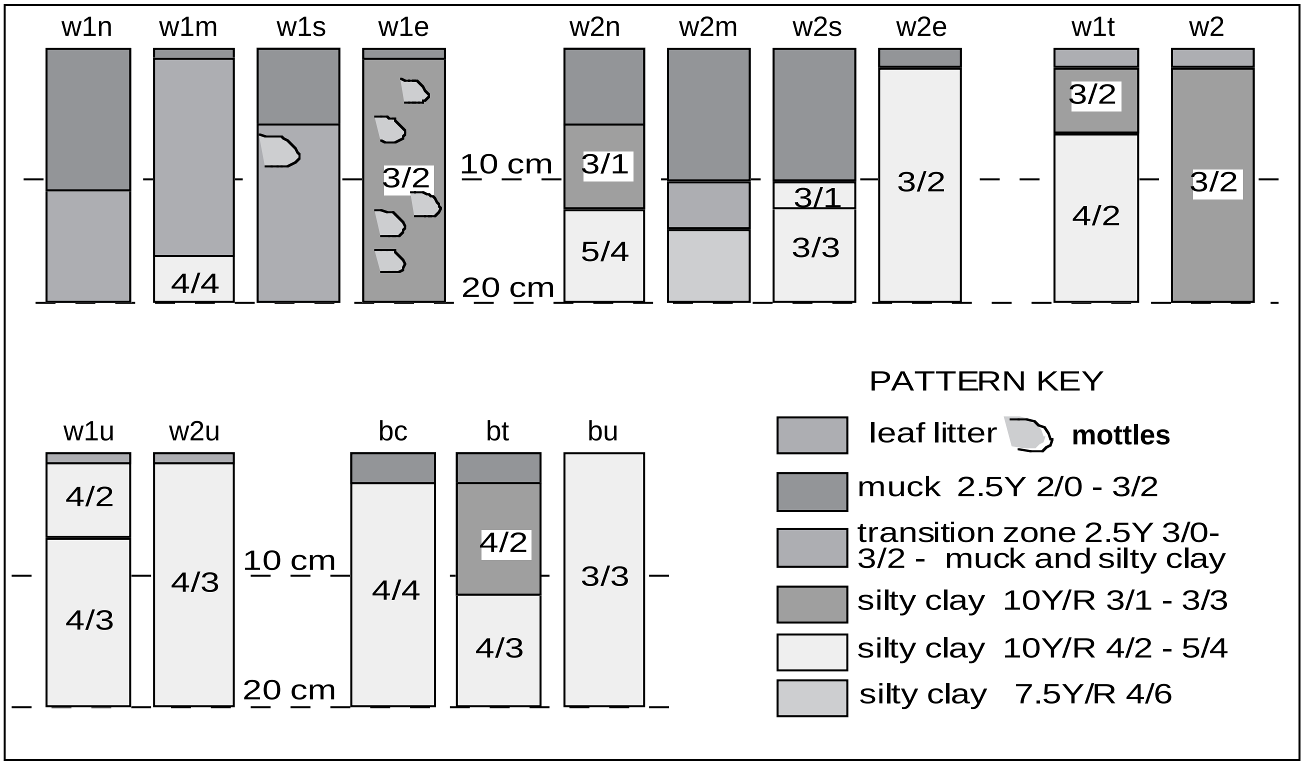

Figure 2. Soil core profiles from selected sampling sites at the ORWRP

located in Wetlands 1 and 2 in the northern deep basin in close proximity to the river inflow pipe (Fig. 4). No carbonate was found in the samples located within the edge samples near Wetland 1 or in either transition zone samples for Wetlands 1 and 2. Billabong samples all had some inorganic carbon present.

Discussion

Soil Color

Since flooding in 1994, the trend in soil hue and chroma has been toward darker colors within the top 8 cm of the soil profiles. Samples from 1998 show the darkest range to date at 2/0 to 3/2 hue to chroma values suggesting the continuance of organic material accumulation within this top layer and continued anaerobic conditions due to the presence of surface water. The top layer of the Billabong soil profiles also show hue and chroma ranges indicative of hydric soils. Their depth of muck layer is, however, much less than the deeper water basins within Wetlands 1 and 2, probably due to the facts that the billabong has only been flooded for just over two growing seasons and the hydrologic nature of this wetland is much different. Not only is the majority of this wetland denuded of surface water for large periods of time, allowing for aerobic organic matter decay, but plants surrounding the deeper water basin are sparse.

Studies by Bishel-Machung et al. (1996) and Confer and Neiring (1996) found soil matrix chroma values within created freshwater emergent marshes to be comparatively higher than those of naturally occurring reference wetlands even after eight years of flooding. Confer and Neiring

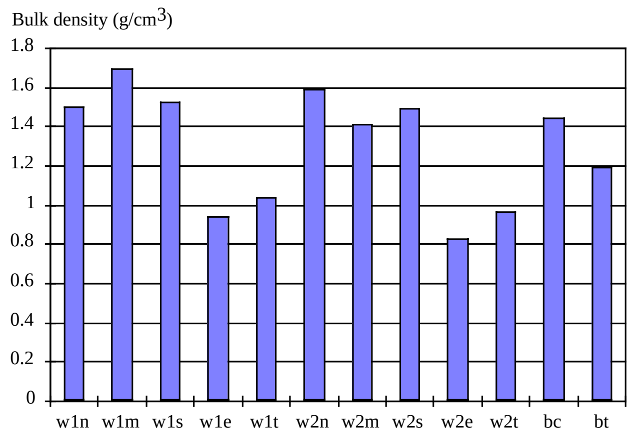

Figure 3. Soil bulk densities for selected sampling sites at the ORWRP

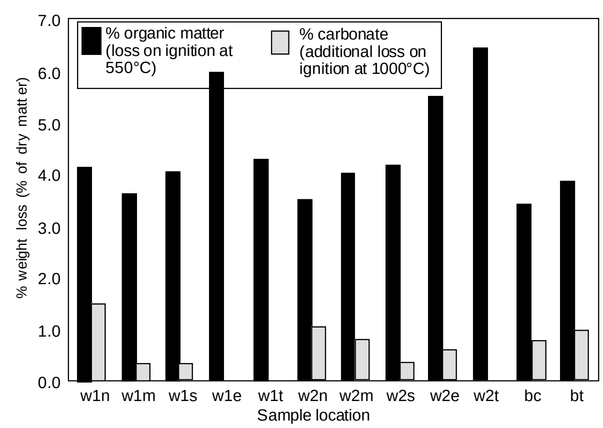

Figure 4. Percent organic and inorganic carbon for soils at the ORWRP

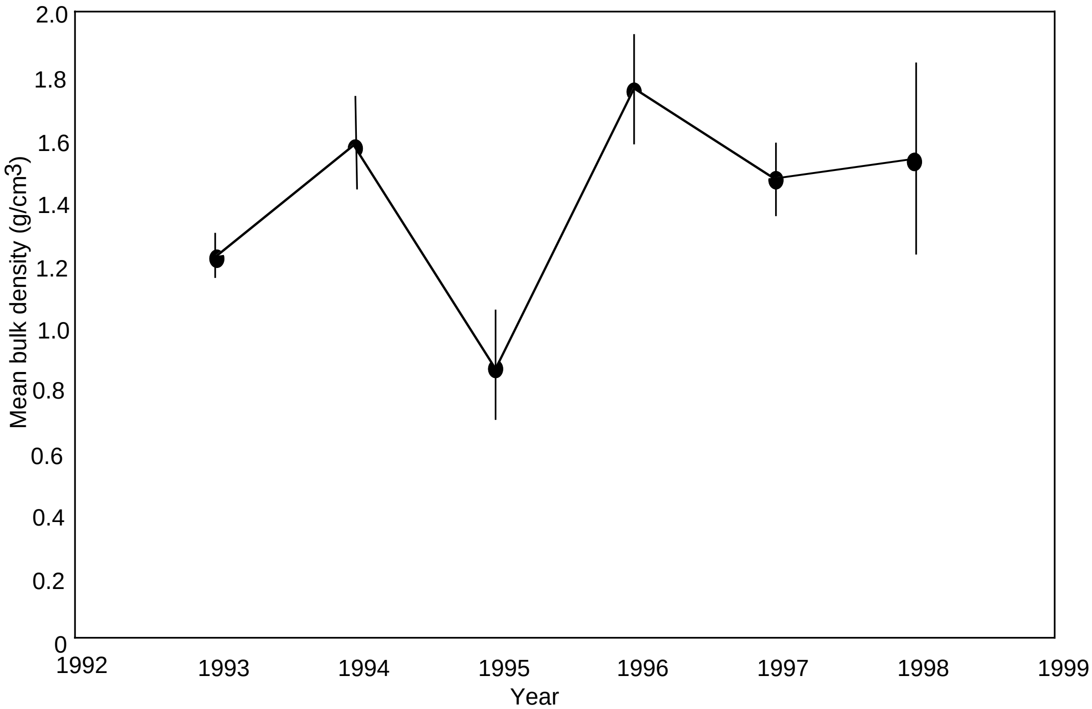

Figure 5. Mean bulk densities for deepwater wetland basin soils at the ORWRP, 1993-1998

(1996) found chroma values of 2 or less present only within one sample of the five created wetlands that were examined while Bishel- Machung et al. (1996) found 63.3% of the soils from 44 creation wetland projects with chroma values of 2 or less. Both studies attributed the higher chroma values for these created wetlands to low organic matter content.

Lower chroma values occurring within the top layers of the ORWRP wetlands suggest that organic matter accumulation rates are occurring faster than those of other created wetland systems. Possible reasons for this occurrence could be the continuous inflow of river water carrying in organic debris and the prevalence of vegetation that has established along the shallower gradients in the systems.

A consideration regarding soil color determination in the field is the rigor of the technique that is predominantly employed. Munsell Colour Charts have generally been the standard by which soil colors have been determined; however, Kuntz (1997) points out that 86% of the color chips from the 1975 soil book charts have become unreliable and one third of the colors in the 1994 version are out of tolerance. The implications of such a finding suggest that comparisons made of soil color between studies may not be all that meaningful unless soil colors show dramatic differences in their values, hues, and chromas. For this particular study, it is assumed that the same Munsell chart has been utilized year to year and that comparisons should be fairly meaningful.

Bulk Density

Significant differences were found to occur between the bulk densities of the soils within Wetlands 1 and 2 and those of the uplands, and transition soils, while no significant difference was found to exist between Wetland 1 and 2 and the Billabong soils. Comparisons made between the 1998 Wetlands 1 and 2 basin soils with those from 1994 showed no significant differences existing for soil bulk density means. Figure 5 shows an interesting trend in bulk density values from pre-flood through post-flood periods. Although sample size and locations are not similar for each of the sampling periods, bulk densities within the range of 1.4 to 1.8 g cm^{-3} appear to be the trend for the years 1994, 1996, 1997, and 1998. Bishel-Machung (1996) found similar results in 44 created wetlands constructed between 1985 and 1991. Those bulk densities averaged 1.15 ± 0.2 g cm^{-3}, while 20 comparative naturally occurring reference sites averaged 0.60 ± 0.35 g cm^{-3} in bulk density values. The lower values in the natural sites were attributed to higher organic matter content.

Organic Carbon

Despite the measurable differences between the organic matter content within all samples obtained including upland at ORWRP, no statistical differences were found to exist (α = 0.05). Comparisons of samples obtained in 1996 and 1997 with those from 1998 also show no significant differences. Low organic matter is expected, given the short temporal period under which the wetlands have been functioning. Bishel-Machung (1996) determined mean percent organic matter values within 44 created wetlands to be 5.7 ± 6.8% at the 20 cm depth while 20 reference sites had mean percent organic matter values of 10.3 ± 11.5% at the 20 cm depth. The organic matter values for the 44 created wetlands are just slightly higher than those found at the ORWRP with a mean of 4.3 ± 0.9%; however, sampling size errors are more likely for the ORWRP.

Inorganic Carbonate

The amount lost on ignition at 1,000°C for all sampling areas were not found to be significantly different at the 0.05 level; no previous years' data are available for this tested parameter. Slightly higher values determined for samples collected near the river inflow pipes within Wetlands 1 and 2 suggest that the river water is the main source. Lower values observed for the southern end of Wetlands 1 and 2 suggest that the majority of the inorganic settles out in the basin before reaching this area. The higher values for the Billabong transition and deep water soils are presumed to be indicative of both a river water and groundwater source.

Conclusions

Analysis of soil changes within these created systems would greatly benefit from a determination of the soil chemistry of the samples collected as well as a larger number of samples collected throughout all three wetlands.

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Appendix A. Bulk density, % organic matter and % carbonate at each sampling stations

Sampling Station	bulk density (g/cm^3)	% organic matter	% carbonate
w1u	0.87	5.1	0
w2u	0.89	6.4	0.6
w1t	1.04	4.3	0
w2t	0.95	6.4	0
w1e	0.93	6.0	0
w2e	0.83	5.5	0.6
w1n	1.48	4.1	1.5
w2n	1.59	3.5	1.0
w1m	1.68	3.6	0.3
w2m	1.39	4.0	0.8
w1s	1.52	4.0	0.4
w2s	1.47	4.2	0.3
bu	1.25	3.6	0.9
bt	1.16	3.9	1.0
bc	1.46	3.4	0.8
mean	1.23	4.53	0.55
st dev	0.29	1.02	0.44