pH and SOC Trends Across an Upland to Fen Transect in Southern Wisconsin

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Introduction

Wetlands were once thought of as nothing more than mosquito breeding grounds, but today they are considered great habitats for many animals and they are useful in filtering pollutants, recharging groundwater and reduce flooding (Richardson and Vepraskas 2001). Wetland restoration has currently started at the Karow's farm outside of Fort Atkinson. The Karow's and friends have been doing a great deal to restore their fen, including burning off old growth, cutting down trees, removing invasive species and conducting a plant survey. They have gone through all of this trouble because fens are rare in the United States (Bedford and Godwin 2003). Calcareous wetlands are rare and highly sought after by conservation biologists due to there development on organic soils instead of mineral soils (Van Hoewyk et al. 2000). Fens are wetlands which are notable by their sturdy relationship to ground water (Bedford and Godwin 2003, Amon et al. 2002). Bedford (1999) argues that fens should have an analysis done before any restoration is even proposed; these analyses should include landscape, climate, pH, soil type and many other factors. Since the Karow Fen is at the beginning stages of development none of these analyses have been undertaken as of yet so I have proposed to undertake some of them. Here I present a study of a fen that is in the process of being restored, in southern Wisconsin, to determine pH and soil characteristics between the fen and the upland adjacent to it, as well as, changes in pH, organic carbon, the fen's calcareousness and soil characteristics at different depths and locations within the fen itself.

Literature Review

Bedford and Godwin (2003) made the first comprehensive atlas of fens in the U.S. by using four methods. They first received information on multiple fen characteristics in the states of Alabama, Arizona, Colorado, Michigan, Montana, New Hampshire, New Jersey, New York, North Carolina, Oregon, Pennsylvania, and Wisconsin. They managed to get this information through the Wetlands Management Network of The Nature Conservancy of New York, which contacted the other wetland management networks for the other areas and asked for the information. They then looked at published literature to find more data on fens in the U. S. After that Bedford and Godwin (2003) asked other scientists who were knowledgeable about fens for any information that they might have on fens, and they received multiple unpublished data sets from many different scientists. Bedford and Godwin (2003) then used all of the data sources that they had found and were given to estimate plant information on fens for each state that they had information on. Bedford and Godwin (2003) then determined the number of fens and their locations to navigable waterways in New York by using a geographical information system; this helped them to build a statewide hydrographic layer using information by county. Bedford and Godwin (2003) accomplished this task by using ESRI ARCVIEW. They also determined the connection between fens and carbonate landscapes for New York and Wisconsin.

Bedford and Godwin’s (2003) study found that fens are a small part of the U. S. landscape and that they most often occur in once glaciated regions, but they have also been found below the limit of glaciation in many states. However, in Wisconsin, fens are abundant and I had no trouble finding a fen for my research. Bedford and Godwin (2003) also found that most fens are small, as in only a few hectares, and that most states have few fens. Also, types of fens and the type and abundance of species in them are caused by climate and the hydrogeologic setting.

Amon et al. (2002) attempt to clarify characteristics of Midwestern temperate zone fens of the USA by using their field data and observations as well as using published reports. Amon et al. (2002) decided to do this because only calcareous fens (fens with deposits of calcium carbonate and some celaphiles) are protected by the government in the Midwestern USA.

Amon et al. (2002) mostly studied fens from eastern Ohio to western Iowa, but also include data from fens in Alaska, Alberta, Arizona, Colorado, Nebraska, South Dakota, North Dakota, Minnesota, Missouri, Michigan, Ireland, Montana, Ontario, Oregon, Quebec, Rhode Island, Washington, West Virginia, Wisconsin, and Wyoming for 17 years (1985 to 2002). Amon et al. (2002) used data from unpublished reports as well as individual author reports. Another aspect of their fieldwork measured water levels thirty minutes after drilling boreholes or in wells that were monitored. They also treated the soil with HCL to determine if the soil contained carbonate, if the soil effuvesced the soil contained significant amounts of carbonate. I did this same experiment to determine if the soil in the Karow Fen contained free carbonate. The soils were dried at 100 degrees Celsius to determine dry weight and bulk density. They then cooked the soil to 450 or

500 degrees Celsius to determine soil organic matter, and they burned the soil to 950 or 1000 degrees Celsius to determine carbonate content. Organic carbon was tested in a similar way for the Karow Fen. Amon et al. (2002) used ICP spectroscopic analysis to determine the phosphorous level in the soil. Finally, Amon et al. (2002) used plant species nomenclature to identify the plants found in the fens.

Amon et al. (2002) found that all Midwestern temperate zone fens are supported by an inflow of at least half of the accumulated water from a groundwater inflow source and that there is a constant water level in areas where the groundwater discharge is the most prevalent. Amon et al. (2002) also determined that fens typically occur at natural land breaks that cause hydrologic gradients causing ground water to reach the surface. In Midwestern temperate zones these breaks are often cause by glacial deposits (Amon et al. 2002). Amon et al. (2002) also state that the soil must be saturated at root system level for most of the year. According to Amon et al. (2002) all Midwestern fen sizes and nature are determined by the hydrology of the subsurface around them. Amon et al. (2002) also found that Midwestern fen peat is derived primarily from sedges and most fens in temperate zones have sapric peat due to their limited input or enhanced output of water. Amon et al. (2002) found that in the Midwest most fen soils contain substances that are not organic matter, such as calcium carbonate from marl. Amon et al. (2002) determined that fens typically have a high level of cations dissolved within the water; however they determined that fens cannot be classified by only looking at the water chemistry. Amon et al. (2002) determined that fens typically have a high level of cations dissolved within the water; however they determined that fens cannot be classified by only looking at the water chemistry. Amon et al. (2002) also found that fens can be classified by plant species in the Midwestern USA, there are approximately 1169 species that occur in fens and 656 of these are obligatory (can only survive in) to fens.

Bowles et al. (2005) determined how the distribution model of fen vegetation, which is patterns and zonation of peatland vegetation due to environmental gradients, corresponds to gradients of substrate chemistry and mineral and nutrient concentration across the juncture of peat and marl substrate, how biomass is distributed across the fen environmental gradient and finding a model distribution in relation to species richness and the fen environmental gradient and biomass. Bowles et al. (2005) studied Bluff Spring Fen in Cook County, Illinois. They collected vegetation data in 1992 in 0.25 m2 plots that were 0.5 m apart along a random transect, only undisturbed sample areas along the transect were used. TWINSPAN and ANOVA were used to calculate plant species percent cover, species richness and also to determine if the null hypothesis, that there is no change in plant species due to gradient and mineral content, was true. Bowles et al. (2005) also calculated the amount of sunlight penetration and plant heights using Li-Cor LI-190 SA at the end of the growing season, this was done by selecting ten random plots along the transect to measure. A one-way ANOVA was used to determine differences between communities. Bowles et al. (2005) tested the substrate from samples taken at 27 randomly selected vegetation plots. These samples were stored in clean polyethylene bags in the refrigerator until analyzed. The substrate was sampled to determine the soil solution that plants get their nutrients from. Bowles et al. (2005) tested for pH by making a 1:1 soil water paste. Bowles et al. (2005) tested the soil for pH, cation exchange capacity, organic carbon content, phosphorous, calcium concentrations, and base saturation percent of K, Mg, Ca and Na.

Bowles et al. (2005) found that 100 percent of plant species were replaced across the fen and the fen was classified into three groups because of this: spring run, graminoid fen (calcareous seep) and sedge meadow; species richness had the same outcome. All three vegetative areas (though at different levels) had a positive correlation to percent base saturation of Mg, while Na and pH had weak positive correlations and Ca had a high negative correlation in some locations and in others the results were flipped, this is due to the high Ca in some areas causing the pH to increase by levels. Organic content was lower in spring runs and higher in graminoid fens.

Methods

The study site, located on Star School Road outside of Fort Atkinson, is in the possession of the Karow Family. They have been restoring the fen for the past couple of years and were glad to have someone study their land. They want to know as much about it as possible to make their restoration successful. Permission was given to me by them to study their property.

Methods for this experiment were conducted both in the field and in the lab. First, I received permission from the owners of a calcareous fen to conduct soil samples. I used a 300 foot tape measure, Munsell Soil Color Charts, Field Book for Describing and Sampling Soils, a Trimble GPS unit, a level and Stadia rod, 10% hydrochloric acid, a soil probe, a compass, sample bags, a marker, flags and a Spectrum Technologies pH tester.

Field Methods

Starting at a corn crib on the property that is up slope from the fen, I laid out a transect due east using the compass as a guide. I then marked every 25 feet with a red flag. I laid out flags from 0 feet to 795 feet, which is the east property line.

Figure.1 The property of the Karow Family. The corn crib is the top building from the southern corner of the corn crib to the far eastern tree line is where the samples were taken.

I then calibrated the Spectrum Technologies pH tester using the points 7.00 and 4.00. I tested the accuracy of the Spectrum Technologies pH tester by testing the same site ten times throughout my testing I tested the site random times within three hours and found that the pH tester is very accurate and only off by a few points occasionally.

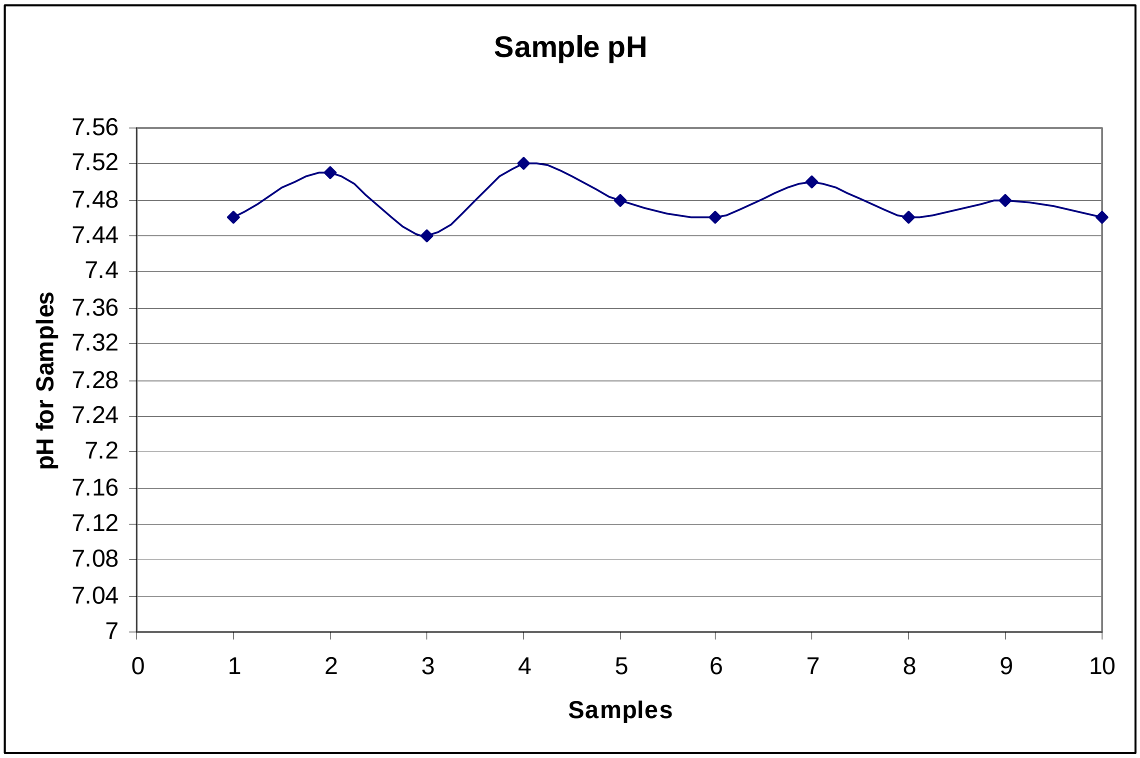

Figure 2. Graph Showing variability of the pH meter in measuring samples.
pH was tested 10 times randomly over a three hour period. All of the pH points are between 7.44 and 7.52 with the mean of 7.47 and a median of 7.46.

After that, I started collecting pH readings and two soil samples for each site from the corn crib to the property line. I collected 33 samples of top soil (A horizon) and 33 samples of soil with multiple horizons. The transect intersected the peat mound on the property, which started sloping up at site 23 and ended its downward slope at site 27. The pH for each site is listed in Table 1.

In the field I also took GPS points at every sample point using the UW-Whitewater Trimble GPS unit. I also collected elevation using a level and Stadia rod with the assistance of Dr. Jacobs.

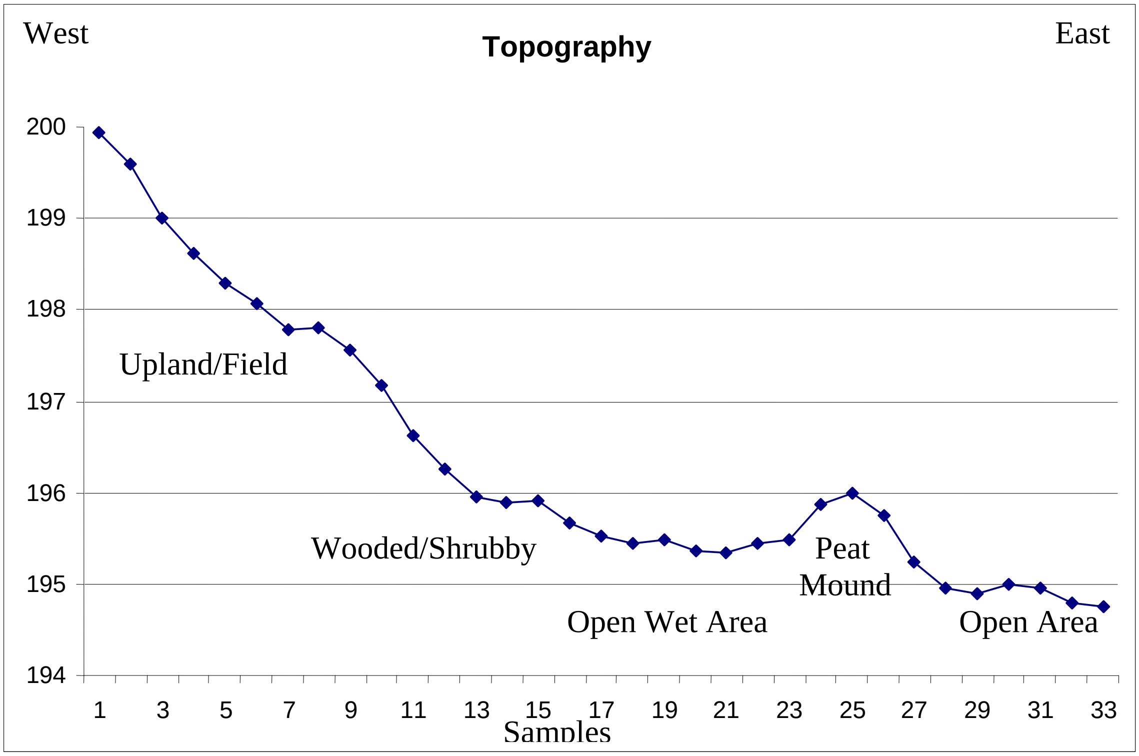

Figure 3. Topography of the Karow land. The degrees above sea level are not accurate 200 was just used as a reference point.

One set of soil samples was used to determine soil type and horizonation for each of the sample sites. These samples were looked at very closely and there coloration was determined by using the Munsell Soil Color Charts. The soil type was determined by using the Field Book for Describing and Sampling Soils and a Texture Triangle.

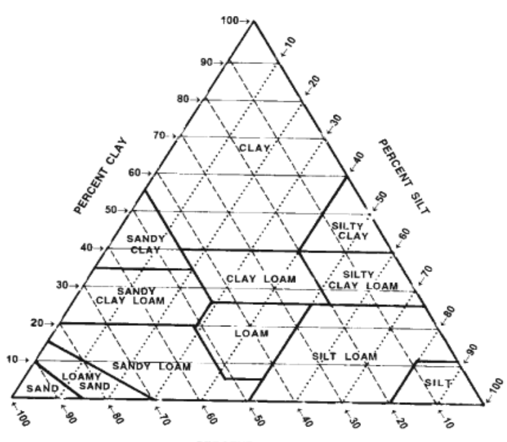

Figure 4. Soil Texture Triangle.

The soil was then labeled for content of each of these using a mater horizons list (Olson 1981).

Lab Methods

In the lab I dried out the samples in an oven at 30 degrees Celsius, so that I could run tests for organic carbon content and to determine where the calcium deposits start (Table 1). After the samples dried I used a mortar and pestle to gently crush the soil. I then sieved them to remove any large particle, debris and rocks and saving the less than 2 mm fraction. I then used a ten percent hydrochloric solution to test for free calcium carbonate. I did this by putting a small amount of soil on a sample tray and then dropping one drop of hydrochloric acid on it and watching the reaction of the hydrochloric acid to the amounts of calcium carbonate in the soil. If the sample did not effervesce there was no free calcium carbonate in the soil, if it effervesced slightly there was a low amount of calcium carbonate, a large amount of effervescing was given a rating of high. After that, I conducted the Loss-on-Ignition method (LOI) to determine the amount of organic carbon in the samples. The loss-on-ignition method is done by placing each of the seived samples into their own crucible then recording the weight for each one. The samples are then dried overnight at 105 degrees Celsius. Then they are weighed again and the oven dried weight is recorded. The samples are finally heated again at 360 degrees Celsius for two hours, then cooled to room temperature and weigh again (Jacobs 2002).

The LOI percent is calculated by using the equation:

$$\%LOI = [(OD\ weigh - LOI\ weight)/(OD\ weight - tare)]*100$$

The equation for organic carbon (OC) is:

$$\%OC = 0.5749*\%LOI + 0.007$$

Sample Number	Distance in Feet	pH	Calcium Carbonate	Organic Carbon %	Description Surface texture, surface color, recognized horizons
1	0	5.01	Low	1.87	Sand, 7.5YR4/4, Ap B C
2	25	7.17	None	2.09	Sand, 7.5YR3/3, Ap B C
3	50	7.61	None	1.25	Sand, 7.5YR3/2, Ap B C
4	75	7.46	None	0.98	Sand, 7.5YR2.5/1 and 7.5YR4/4, Ap B C
5	100	7.54	None	1.41	Sand, 7.5YR2.5/1 and 7.5YR4/4, Ap B C
6	125	7.98	None	1.53	Sand, 7.5YR2.5/1 and 7.5YR4/4, Ap B C
7	150	7.64	None	1.15	Sand, 7.5YR2.5/1 and 7.5YR4/4, A E B C
8	175	6.76	None	2.10	Sandy Clay Loam 7.5YR3/1 and 7.5YR4/4 A E Bt C
9	200	5.72	None	1.43	Sandy Clay Loam 7.5YR3/1 and 7.5YR4/4 A Bt C
10	225	6.37	None	2.38	Sandy Clay Loam 7.5YR2.5/1 A Bt C
11	250	6.96	None	3.73	Silty Clay Loam 2.5/10Y and 7/10Y A Btg C
12	275	7.07	None	3.13	Silty Clay Loam 2.5/10Y and 7/10Y A Btg C
13	300	7.18	None	11.01	Silty Clay Loam 10YR2/1 A Bt C
14	325	7.02	None	14.88	Silty Clay Loam 10YR2/1 A Bt C
15	350	7.54	None	18.83	Silty Clay Loam 10YR2/1 A Bt C
16	375	7.47	None	7.49	Silty Clay Loam 10YR2/1 and 10YR5/4 A Btg C
17	400	7.84	None	4.60	Silty Clay 2.5/10Y and 6/10Y A Btg C
18	425	7.71	None	3.32	Clay 2.5/10Y and 6/10Y A Btg C
19	450	7.75	None	3.23	Clay 2.5/10Y and 6/10Y A Btg C
20	475	7.97	Low	5.70	Clay 2.5/10Y and 7/10Y A Btg C
21	500	7.81	Moderate	3.06	Clay 2.5/10Y and 7/10Y A Btg C
22	525	7.46	None	3.42	Clay 2.5/10Y A Btg C
23	550	8.27	None	4.87	Clay 2.5/10Y A Btg C
24	575	7.06	None	12.12	Loamy Clay 10YR2/1 A Bt C
25	600	7.02	None	23.16	Sandy Clay Loam 7.5YR2.5/1 A Bt C
26	625	7.93	Low	24.18	Clay 2.5/10Y A Btg C

27	650	8.28	Low	17.69	Silty Clay Loam 10YR2/1 A Bt C
28	675	8.18	Moderate	3.89	Clay 2.5/10Y and 6/10Y A Btg C
29	700	8.14	Moderate	2.65	Clay 2.5/10Y and 6/10Y A Btg C
30	725	8.26	Moderate	2.72	Clay 2.5/10Y and 6/10Y A Btg C
31	750	8.32	High	2.03	Clay 2.5/10Y and 6/10Y A Btg C
32	775	8.35	High	3.63	Clay 2.5/10Y and 4/10Y A Btg C
33	795	8.40	High	3.70	Clay 2.5/10Y and 4/10Y A Btg C

Table 1. Lists the sample number, the distance in feet the sample is from the starting point at the corn crib, the pH values, the amount of free calcium carbonate is in each sample, the percent of organic carbon in each sample using the LOI method, and the Description of the soil, which includes the soil type, soil color and the horizonation.

Analysis

I split the data in half at sample 16. Samples 1 through 16 where used on one side of the test and samples 17 through 33 were on the other, due to this being a place where the tree line ends and the fen seems to start, and used an unpaired student's t-test to determine if there is a difference in pH between the first part of the fen/upland area and the second part of the fen. I assumed that the probability for a difference was 0.001 for this t-test.

I also used the unpaired student t-test to determine if there was a significant difference between the pH on the top of the peat mound compared to the bottom. I assumed that the probability of difference was 0.000 for this t-test. I also calculated the mean and median for each part of both t-tests. I also calculated the standard deviation for each test and for each part of each test. The confidence interval for the mean for each part of the t-tests was also determined.

Results

The calcareous testing showed that there were significant amounts of free calcium carbonate in the soil just before the peat mound at sites 20 and 21. The testing also showed that there were significant amounts of calcium carbonate in the soil on the slope of the peat mound and beyond, from site 26 to 33 with the amount of calcium increasing steadily from sites 26 to 33.

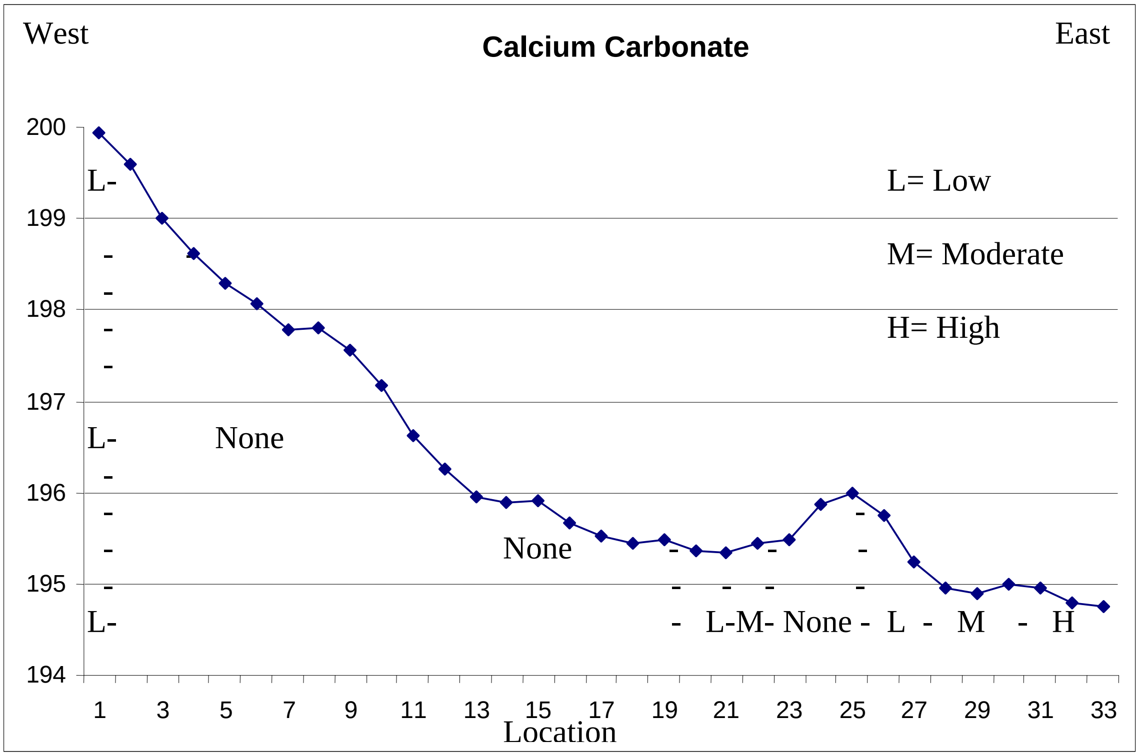

Figure 5. Shows the amount of free calcium carbonate at each location of the fen using general measures of none, low, moderate and high amounts.

The soil samples show that much of the land has wetland soil due to the relatively high pH, the soil type being comparable to wetland soils, and the small amount of organic carbon at each location, but the most wetland prevalent areas are just before the peat mound and the soil after the peat mound. These having high pH, wetland soils and high amounts of organic carbon as well as free calcium carbonate.

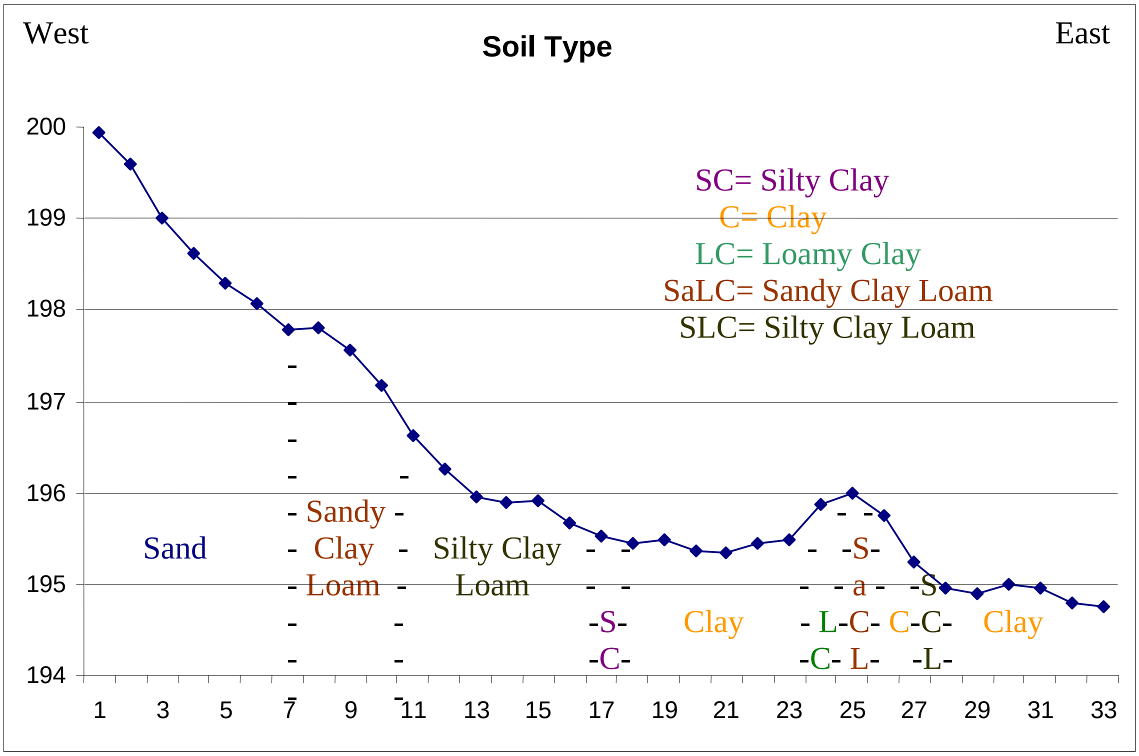

Figure 6. The type of soil at each sample site based on the soil texture triangle.

The Loss-On-Ignition test showed that there are two major places that are composed of organic matter. While all of the sites contain organic matter to a small extent, the sample sites13,14 and 15; as well as, the sample sites 24,25,26,and 27 show a significant increase in organic content compared with the rest of the data.

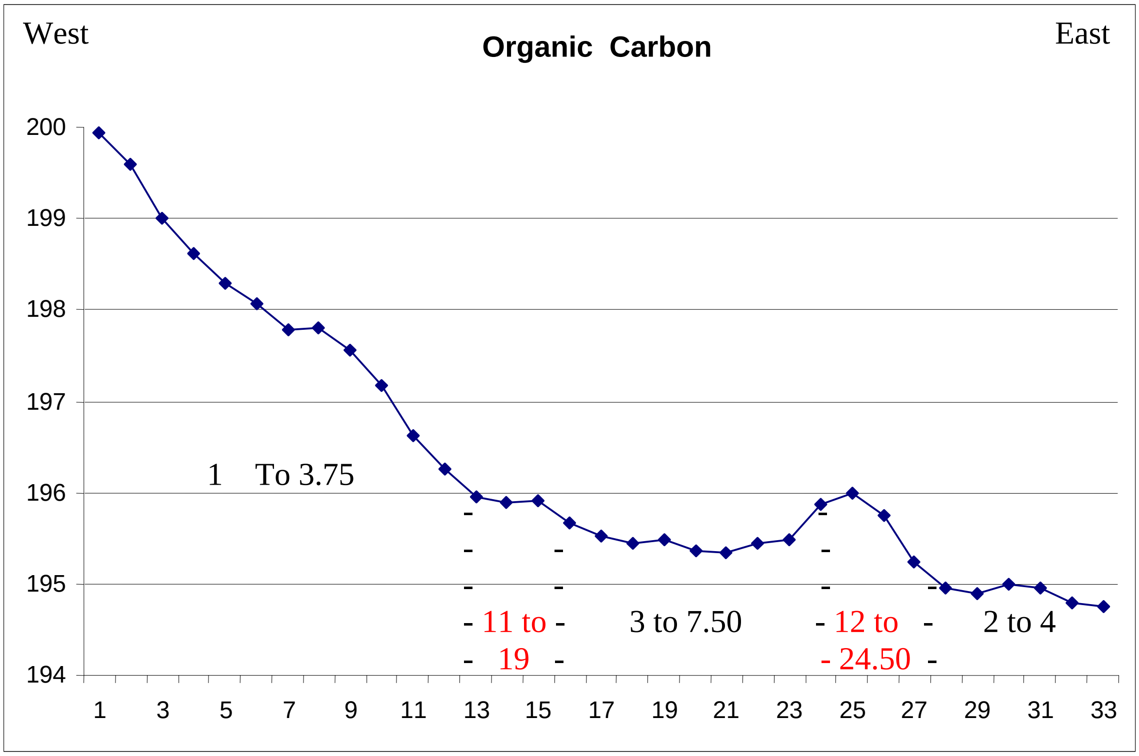

Figure 7. Organic carbon content in the soils. Notice that the large jumps in amount of organic carbon are in read.

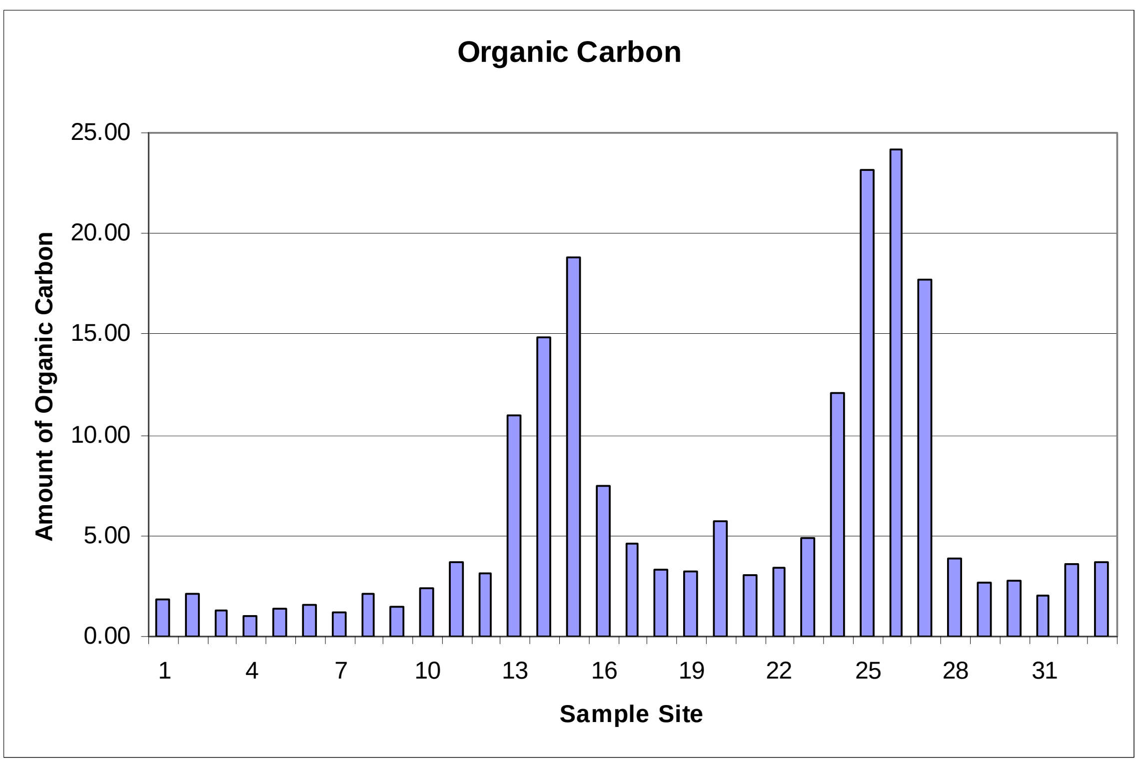

Figure 8. Graph shows the increase in organic carbon at the different sites on the Karow's fen.

The unpaired student t-test shows that there is a significant difference, with the results of -3.87, in pH between the first and second part of the fen. The t-test results were -3.87 with a standard deviation of 0.632 and 31 degrees of freedom. The mean pH for the first part of the fen is 7.08. The median is 7.18 and the standard deviation is 0.770. The mean pH for the second part of the fen is 7.93. The median is 8.05 and the standard deviation is 0.440. There is a significant difference for both areas of the fen.

The unpaired student t-test for the pH of the peat mound and surrounding area shows a significant difference as well. The t-test results were 4.81 with a standard deviation of 0.332 and 17 degrees of freedom. The mean pH for the peat mound is 7.10. The median is 7.04 and the standard deviation is 0.263. The mean pH for the surrounding soil is 7.83. The median is 7.95 and the standard deviation is 0.383. There is a significant difference between both areas of the mound.

Discussion

The Karow's fen, although not very calcareous in many places, is indeed a calcareous fen. The pH is high enough in places, the free calcium carbonate is high enough in some places, there is standing water most of the year, the organic carbon levels are high enough in some places, and the soil type is accurate for a wetland.

The peat mound is very interesting in this fen due to its "low" pH, yet high organic carbon content. This may be due to the peat mound being leached. This may be occurring because the mound has risen so much that there is no groundwater reaching the surface of the mound while the rain water is filtering through the mound and pulling all of the free calcium carbonate and other minerals down. The removing of these minerals through leaching would cause the pH to be lowered, however, the mound was originally composed of organic matter so the mound is still mostly constructed of organic matter (organic carbon). To test this hypothesis I suggest that piezometers are placed on the mound at different depths and piezometers next to the mound at different depths.

Another strange thing about this fen is that the highest pH is near the very end of the fen. This is most likely where the underground springs are now flowing. This would make sense because, according to the Karow family, who have done studies on the taxonomy of the plants, this is the place that the most obligate calcareous wetland plants are growing. These obligate plants must grow in wet soil that is high in pH and must be calcareous (Nekola 2004, Bedford et al. 2006).

The Karow family has a calcareous fen on there property that is definitely worth restoring. The fen is already well on its way to being the natural refuge it once was for wildlife in the area, I have witnessed sandhill cranes, red tailed hawks, roughed grouse, many wild flowers and much more. This fen will be a sight to behold when the restoration is finished.

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