SOIL ANALYSIS OF A SLOPE IN THE LONG ISLAND PINE BARRENS

Adam Adler[1], Eli Rosofsky[1], Ian Wong[1], and D. K. McDaniel[2]
[1]Ward Melville High School, East Setauket, NY 11733
[2]Dept. ESS, SUNY, Stony Brook, NY 11794-2100

Introduction

In this paper, we report the results of our research into the effect of slopes on soil profile development. The study focused on ~2,500 acre part of the Central Pine Barrens near Westhampton, Long Island, called the Long Island Dwarf Pine Plains. This region has an unusual ecosystem, with rarely found plant and animal species, especially the undersized pitch pines and scrub oak that have an average height of 1.5 to 2 meters. Only three such miniature woodland regions are known to exist, the Shawangunk Mountains Dwarf Pine Plains and a region in New Jersey being the others. Yet, surrounding these regions are normal sized (6-7.5m, 20-25 ft) pines and scattered oaks (Miller et al., 1996). The reasons for the stunted growth of the trees is unclear. One possibility is that poor soil conditions leads to dwarfing (Cryan, 1982). It is known that soil horizons can vary along slopes, a feature called a soil catena (for example, see Ritter, 1986). Since the Long Island Dwarf Pine Plains are in a region with rolling topography, we thought that soil profiles should vary along slopes. To test this hypothesis we described and analyzed soils from three holes along a hillside: from the bottom, top, and midway up the slope. Most of the analyzed soils are classified as slightly gravelly (pebbly) sands. There are distinct differences in soil horizon development between the three holes, with soils more deeply developed at the bottom of the slope than at the top. On the basis of our results, we suggest that studies attempting to compare stunting of pitch pines in the Pine Barrens to soil composition should take into account local variations in soil characteristics and nutrient supply.

Background

The Long Island we know today was formed by Pleistocene glaciers that molded irregular lines of hills in an east-west orientation. These are glacial moraines, formed at the edge of the glacial ice sheet. Most of the material in the moraines is glacial till, an unsorted mixture of boulders, pebbles, sand, soil and clay. Other glacial formations on Long Island are outwash plains; flat areas along the south shore and between moraines. These are formed by coalescing deltas deposited by glacial meltwaters. The soils of moraines and those of outwash plains are quite different due to the greater degree of sorting in the outwash plain system. The degree of sorting should have a major impact on the porosity and permeability of the resultant soils. Soils affect plant growth, thus vegetation types can be influenced by soil profile characteristics (Richards, 1996).

Today, growing on top of the accumulated sediments of Long Island are the Central Pine Barrens, covering an area of barely 100,000 acres. Soil forming processes produce variations in composition, texture, structure, and color at different depths (called soil horizons). An idealized soil profile consists of four basic horizons. At the top, the O horizon is organically rich, biologically active, and contains some mineral matter. The A-horizon immediately below this contains mainly mineral matter as well as some partially decomposed organic matter (Press and Siever, 1982). This is followed by the B-horizon, with soluble minerals, iron oxides, and little organic material. Finally, the C-horizon is defined as slightly altered bedrock (Tarbuck and Lutgens, 1984). On Long Island the 'bedrock' consists of glacial-age quartz-feldspar sand.

Methods

In order to understand how soil profile development relates to position on a slope, we dug three holes at different heights along a suitable slope, described and tested the soils, and took samples back to the lab for grain-size analysis. We conducted our field research on October 19, 1996. We chose a slope ~300 meters west of Riverhead Road, and ~42 meters north of an E-W trending dirt road that is ~1km meters north of the Suffolk County Airport. By pacing and using a Brunton compass, we measured the slope to have an incline of approximately 6%. Hole AA situated in the valley, hole ER was just under halfway up the slope, approximately 47 meters from AA, and hole IW was near the top, approximately 70 meters from hole ER.

We dug each hole to a depth of approximately 20 inches (51 cm). We described and took small samples at each soil horizon or 5 inches (12.7 cm) intervals, whichever was smaller, and measured their depths with a ruler. We then combined these samples with distilled water and measured the pH using litmus paper (4.0 to 7.0 range, in 0.3-0.4 units). The temperature of the soil was also taken every 12.7 centimeters by inserting a thermometer into the soil and reading it after approximately one minute.

We collected 300 to 400 grams of soil for lab testing. From any soil sample that contained pebbles we took four bags, or 1 to 3 kg. This allowed us to get a representative sample of the soil according to standard grain-size lab techniques (Folk, 1988; and Lewis, 1984).

The same evening, we weighed out 10-26 g aliquots of each sample and dried them overnight at about 100ºC. After cooling the samples in a desiccator, we reweighed the samples and calculated the percent moisture content.

The remainder of the samples were oven-dried, and two samples from each hole were selected for a careful study of grain size distribution. These were carefully disaggregated, and sieved following the procedure outlined in Folk (1988) fairly strictly. The samples were homogenized and split into 25% aliquots, using cone and quarter techniques (Lewis, 1984), until a 60 to 100 gram aliquot representative of the entire sample was obtained. We selected 11 steel-screen sieves at intervals of one half phi (ϕ) size (Krumbein Size Scale, where $\phi = -\log_2 x$, and x is in millimeters) from -1ϕ to 4ϕ, plus a collection pan. We divided these sieves into sets of six (inserting one extra sieve to fill the space in the second set), and sieved each set with a Tyler automatic shaker for 15 minutes. Sand grains from each sieve were carefully tapped onto a large sheet of freezer paper, and weighed using a Mettler electronic balance. A laboratory sand sample, sieved as a control, agreed with other worker's analyses to within 4%. We modified this procedure for two of the sample (IW2 and ER3) with pebbles. In these cases, we first weighed the entire sample, manually passed it through a -1ϕ screen, then manually sorted and weighed all the larger pebbles. The subsample which was smaller than -1ϕ, was then aliquoted and sieved as above. In order to evaluate possible errors due to sample loss (spilling), samples weights before sieving were compared with sums of the grain sizes. For one sample (ER2), 6% of the sample may have been lost. All other totals indicated 2-3% loss.

Results and Discussion

The results of field measurements and moisture contents are shown in Table 1, and the results of grain-size analysis of samples IW2, IW3, ER2, ER3, AA2, and AA3, are summarized in Table 2. Figure 1 shows the profile of the slope to scale (no vertical exaggeration), with the holes labeled at the appropriate places. Beneath each hole the respective values we determined and measured are shown. These include soil horizons, moisture contents, pH, temperature, mean grain size, and sorting.

Although Westhampton received ~5 inches of rain the day before we sampled, that afternoon was cloudless and cool. We noticed first of all, that all of the soils were damp when we sampled them, even at the shallowest levels. For each hole, we found well-developed horizons to describe and sample. The O-horizon was comprised mostly of black, charred (from a recent fire) organic material, mixed with more fresh leaves and pine needles. The A-horizon consisted of buff colored sands, and

TABLE 1. FIELD MEASUREMENTS

Sample	Depth (inches)	%H_2O	pH	Temp (°C)
IW1	0	22.73	4.45	14
IW4	-2.5	7.66	4.4	
IW3	-5	8.21	4.15	14.5
	-10			14.25
IW2	-12	8.56	4.55	
	-14			14
ER1	0	11.82		
ER2	-3	5.64	4.3	15.5
ER4	-5	6.68	4.25	15.5
	-10			15.25
	-15.5		4.05	15
ER3	-20	8.04		
AA1	0	63.55	4.2	17
	-5		4.2	16
	-10		4.3	14.5
AA2	-12.5	4.90		
	-15			14
AA3	-18.5	8.32		
	-20		4.4	14

TABLE 2. GRAIN SIZE DISTRIBUTION OF LONG ISLAND SOIL SAMPLES

Grain size		**IW3 (-5")**		**IW2 (-12")**		**ER2 (-3")**		**ER3 (-20")**		**AA2 (-12.5")**		**AA3 (-18.5")**	
mm	**ϕ**	**mass (g)**	**%**	**mass (g)**	**%**	**mass (g)**	**%**	**mass (g)**	**%**	**mass (g)**	**%**	**mass (g)**	**%**
Total mass →				2713				989					
32	-5			65.93	2.43				0.00				
16	-4			45.83	1.69			7.86	0.80				
8	-3			43.98	1.62			23.75	2.40				
4	-2			13.40	0.49			6.73	0.68				
Sub-Total →				169.13				38.34					
Aliquot →		81.35		71.47		73.28		65.41		95.61		73.42	
Organic matter		0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.0	-1.0	0.45	0.56	0.72	0.96	0.29	0.43	0.48	0.72	0.36	0.39	0.89	1.25
1.4	-0.5	0.89	1.12	0.57	0.76	0.74	1.08	0.61	0.92	1.14	1.23	0.89	1.24
1.0	0.0	3.37	4.22	2.56	3.43	3.33	4.84	2.79	4.19	4.40	4.76	3.33	4.68
0.71	0.5	7.06	8.83	7.21	9.64	7.26	10.56	7.28	10.94	10.61	11.46	7.25	10.18
0.50	1.0	16.94	21.18	13.11	17.53	14.85	21.61	13.61	20.45	20.99	22.67	15.15	21.25
0.35	1.5	22.63	28.30	19.46	26.02	23.72	34.51	19.07	28.66	31.22	33.73	23.58	33.09
0.25	2.0	13.69	17.12	11.03	14.75	12.72	18.51	10.31	15.50	16.36	17.67	13.99	19.63
0.177	2.5	4.59	5.74	4.58	6.13	3.75	5.46	3.63	5.46	5.27	5.69	4.49	6.29
0.125	3.0	2.80	3.50	2.36	3.16	1.45	2.11	1.47	2.21	1.49	1.61	0.32	0.45
0.088	3.5	0.60	0.76	0.88	1.18	0.28	0.41	0.62	0.93	0.17	0.18	0.29	0.40
0.063	4.0	1.00	1.24	1.41	1.88	0.33	0.47	0.85	1.28	0.12	0.13	0.29	0.41
0.044	4.5	5.94	7.43	6.24	8.35	0.00	0.00	3.23	4.86	0.45	0.49	0.81	1.14
Sum Wt. →		79.96	100.00	70.14	100.00	68.73	100.00	63.95	100.00	92.58	100.00	71.27	100.00
% Lost →		**2%**		**2%**		**6%**		**2%**		**3%**		**3%**	

3

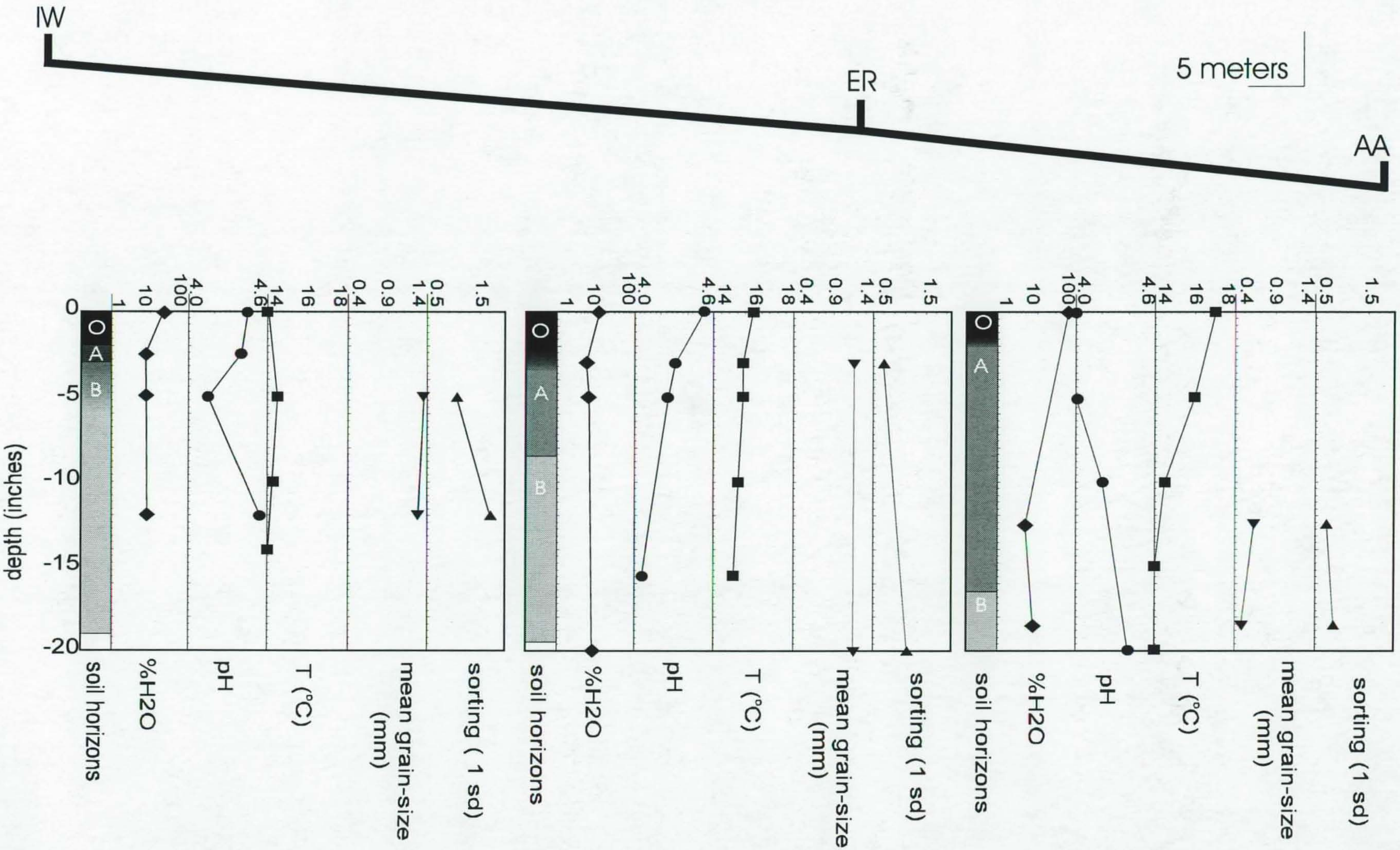

Figure 1. Graphical presentation of field data and sieve analysis data for three holes from the Long Island Dwarf Pine Plains (IW, ER, and AA). The slope and sample locations at the top are to scale (no vertical exaggeration). Shown on the sets of plots for each hole are from left to right: soil horizon contacts and thicknesses; percent moisture content, pH, and temperature measurements; graphically determined mean grain-size; and the standard deviation of the grain size distribution (a measure of sorting where high standard deviations correspond to poor sorting).

4

the B-horizon was characterized by distinctly red-colored sands. We noticed that sands of the B-horizon held together in a loose ball when damp, indicating a significant clay content. We never reached a C-horizon in any hole. From Figure 1, it can be seen that at hole IW, the highest sampling area, the O, A and B horizons were all found within the first 6 inches (15 cm). The mid-slope hole, ER, had expanded soil horizons, so that the O and A horizons went to about 8 inches (20 cm), and the B horizon continued down through the bottom of the hole. The lowest hole, AA, had the most expanded soil horizons, such that O and A continued down to about 16 inches (41 cm), and the B horizon continued beyond the bottom of the hole. This characteristic of soil profiles being more deeply developed near the bottom of a slope than at the top is a geomorphic feature known as a soil catena (for example, see Ritter, 1986).

The temperature in each hole decreased with depth; although the change was not as significant in IW (Figure 1), probably because the sun was setting by the time we sampled it. There was no conclusive trend in pH with depth of each hole. All measurements ranged between 4.0 and 4.6. However, there was a distinctly higher pH in IW and ER (the two higher holes) than in AA (Figure 1).

The shallowest horizon (O), containing the most organic material, had the greatest water content in each hole, and the water content of AA1, the O-horizon sample of hole AA, is about 40% greater than all the other samples. We believe this is because it rained 5 inches the day before we collected samples. The water probably percolated down-slope and saturated the soil.

Grain-size analysis of the sands show that their most common (modal) grain size is 1ϕ to 1.5ϕ (medium sand). Three of the samples are bimodal (IW2, IW3, and ER3) with minor peaks at grain sizes smaller than 4ϕ (silt). Our data are similar to those recorded previously on a different area within the Long Island Pine Barrens (Beccaria, 1995). We calculated graphical mean grain sizes for each sample from cumulative percent curves (Lewis, 1984). These are plotted as a function of sample depth in Figure 1. The mean grain size decreased with height on the slope, from -0.5ϕ (very coarse sand) at hole IW on top of the slope to 0.75ϕ (coarse sand) at hole AA in the valley. We interpret that this trend is probably inherited from the original geology (glacial sediments), but could also be caused by slope sedimentary processes. The standard deviation of grains sizes can be used as a measure of how well-sorted the sand is (Lewis, 1984). The standard deviation of the grain sizes is from 0.7 to 1.7 mm, indicating that the sands are moderately to poorly sorted (Lewis, 1984).In each hole, the sorting of the soil becomes worse with depth (Figure 1). We interpret that this is a result of water percolating downward and carrying silt- and clay-sized particles along with it.

Figure 2 is a ternary plot of gravel vs. mud vs. sand (after Folk, et al., 1970), on which the samples we analyzed are plotted. According to this classification scheme, these samples are classified as slightly gravelly (pebbly) sands. We expect that sands of this class should have low moisture-retention capacities. Even so, the 4ϕ (silt) and finer fraction is significant, comprising nearly 10% of some samples, suggesting that it would be worth investigating this aspect further.

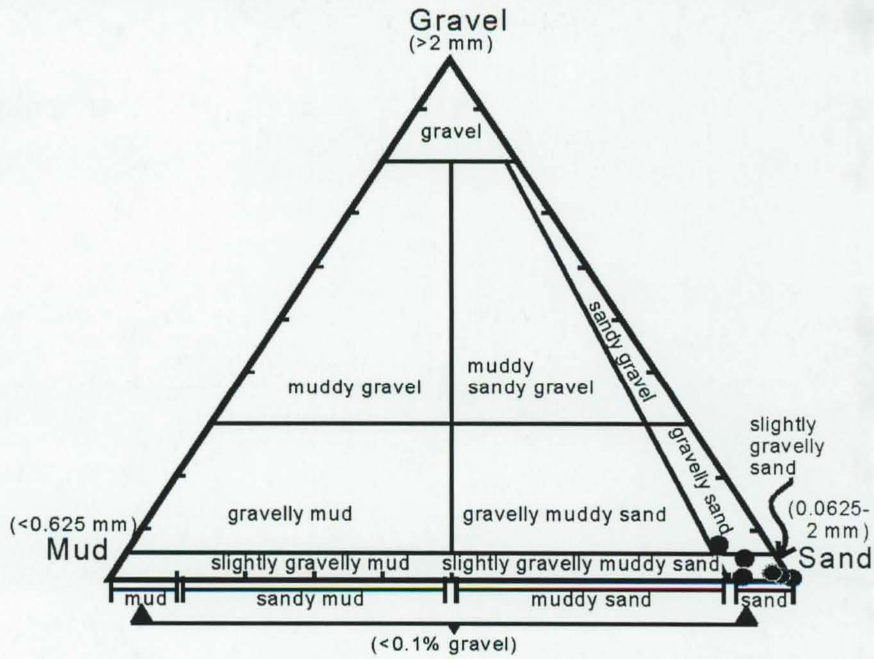

Figure 2. Ternary plot of Gravel vs. Sand vs. Mud. Sands from this study are classified as slightly gravelly sands. Classification from Folk et al. (1970).

A soil's fertility is controlled by factors that are complex and too numerous to list here. A few obvious ones however, include the availability of organic matter, the availability of water, and the mineralogic composition of the soil. Soil texture (or the grain-size distribution) significantly affects the moisture retention capability of the soil. This can then affect rates of weathering in the profile, which in turn controls the stability of different minerals, and the nutrients released from minerals into the soil. Thus, if soil profiles can change dramatically over a distance of ~120 meters as we have shown, it is possible that the fertility of the soil can change as well, possibly influencing vegetation growth. Specifically, studies that attempt to correlate dwarfing of pitch pines to soil characteristics should keep in mind that a soil sampled in one shallow spot will probably not accurately reflect the composition of soil in the entire area.

Conclusions

1. Analyzed soil samples from the Long Island Dwarf Pine Plains may be classified as slightly gravelly (pebbly) sands, with up to nearly 10% silt-sized and finer particles.
2. Soil profile depths change with altitude along the slope. Soil horizons in the valley appear deeper and are thicker than those at the top of the slope.
3. The mean grain size of the soil decreases down-slope, with sands in the valley having mean grain sizes that are smaller than at the top of the slope.
4. For each hole the soil becomes more poorly sorted with depth.

On the basis of our results, we suggest that studies attempting to compare Pine Barrens stunting to soil composition should take into account local variations in soil characteristics and nutrient supply.

Acknowledgments

We wish to thank Gil Hanson and Scott McLennan of the Dept. of ESS at SUNY Stony Brook. They allowed almost unlimited access to their computers and experimental equipment. Geff Rawling of ESS kindly spent a sunny Saturday teaching us some of the methods and philosophies of field work.

We also wish to thank our parents, who drove us back and forth from the lab just about every weekend. They also gave us aesthetic advice on our display and helped us when there were problems with the computers.

Finally, we wish to thank Ms. Krieger, at Ward Melville High School, for giving us the opportunities to go a step further and perform actual experiments into the mysteries of science.

References Cited

Beccaria, M., (1995) A Study Comparing the Soil Size to Tree Height in the Long Island Dwarf Pine Plains. Unpublished report furnished by Glenn Richards of the Long Island Museum of Natural History.

Cryan, J. F., (1982) The Long Island Dwarf Pine Plains: Pygmy Forests of the Pine Barrens. The Heath Hen. Vol. 1 No. 4.

Folk, R. C., (1980) Petrology of Sedimentary Rocks. Hemphill Publishing Company.

Folk, R. C., Andrews, P. B., and Lewis, D. W., (1970) Detrital sedimentary rock classification and nomenclature for use in New Zealand, New Zealand Jour. Geology and Geophysics, vol. 13, pp. 937-968.

Lewis, D. W., (1984) Practical Sedimentology. Hutchinson Ross Publishing Company.

Miller, W., Vodicka, J. & Vorwald, G., (1996) Pine Barrens Sediments. Long Island's Natural Environment On Line. Center for High Pressure Research at the State University of New York at Stony Brook. Available: http://www.chipr.sunysb.edu/eserc/rpesc/group1.html

Press, F. and Siever, R., (1982) Earth. W.H. Freeman and Co. 1982.

Tarbuck, E. J. & Lutgens, F. K., (1984) The Earth. Merrill Publishing Co.

Richards, G., (1996) Geology of Long Island. Long Island's Natural Environment On Line. Center for High Pressure Research, SUNY Stony Brook. Available: http://www.chipr.sunysb.edu/eserc/rpesc/group1.html

Ritter, D. F., (1986) Process Geomorphology. Wm. C. Brown Publishers.