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BELOW THE SALT MARSH SURFACE

VISUALIZATION OF PLANT ROOTS BY COMPUTER-AIDED TOMOGRAPHY

BY LINDA K. BLUM AND EARL DAVEY

As sea level rises, salt marshes become subtidal mudflats unless soil surface accretion occurs at rates fast enough to keep the marsh from being submerged (Brinson et al., 1995). The individual processes contributing to accretion are well known but vary geographically in their relative importance. While the complicated interactions among accretion processes are poorly understood (Murray et al., 2008), production of roots and rhizomes is critical to maintenance of salt marsh soil structural integrity and marsh-surface elevation. Many long-term coastal research programs seek to understand how these interactions influence accretion to more accurately predict salt marsh response to sea level rise under widely differing rates of relative sea level rise, tide ranges, sediment supplies, nutrient inputs, coastal geomorphology, and climate.

The roots and rhizomes of salt marshes bind soil particles together to hold them in place, they occupy space in the soil, and they are the primary source of plant material forming peat (Chmura, 2011; Deegan et al., 2012). Factors such as nutrient enrichment (Darby and Turner, 2008; Deegan et al., 2012) and hydroperiod (Niering and Warren, 1980) can alter the production of roots and rhizomes. The importance of belowground plant growth to salt marsh integrity and peat formation was recognized at least by the 1970s (Good et al., 1982), but methodological differences and difficulties measuring the abundance of roots and rhizomes have limited the ability to make widespread comparisons and to generate information about how root growth affects marsh surface elevation relative to surface processes such as mineral sediment deposition or aboveground production (see Morris et al., 2013, in this issue). Estimates of the abundance of roots and rhizomes are essential to understanding these complex, nonlinear interactions among salt marsh accretion processes and to sufficiently predict how salt marshes will respond to sea level rise.

The approaches used to measure the abundance of roots differ widely. Some are subjective and almost all involve the tedious and labor-intensive sorting of live roots from those that have died by hand (e.g., Schubauer and Hopkinson, 1984; Blum, 1993; Darby and Turner, 2008). Computer-aided tomography (CT) offers an opportunity to determine coarse root, rhizome, and peat mass in order to examine factors controlling root dynamics at scales relevant to questions of marsh integrity. This approach is based on differential absorption of x-rays of soil components in intact soil cores (see Davey et al., 2011). While CT imaging provides a direct, nonsubjective measure of root and rhizome volumes, it is not clear if CT-generated volumes provide realistic estimates of root and rhizome volumes and biomass.

Here, we present a comparison between root and rhizome volumes measured in the laboratory by water displacement to those determined by CT-image analysis of soils from two salt marshes at the Virginia Coast Reserve Long Term Ecological Research Site. Both marshes are dominated by *Spartina alterniflora*, have similar geomorphic settings and hydroperiods, and are flooded by water with similar water-quality characteristics and salinities.

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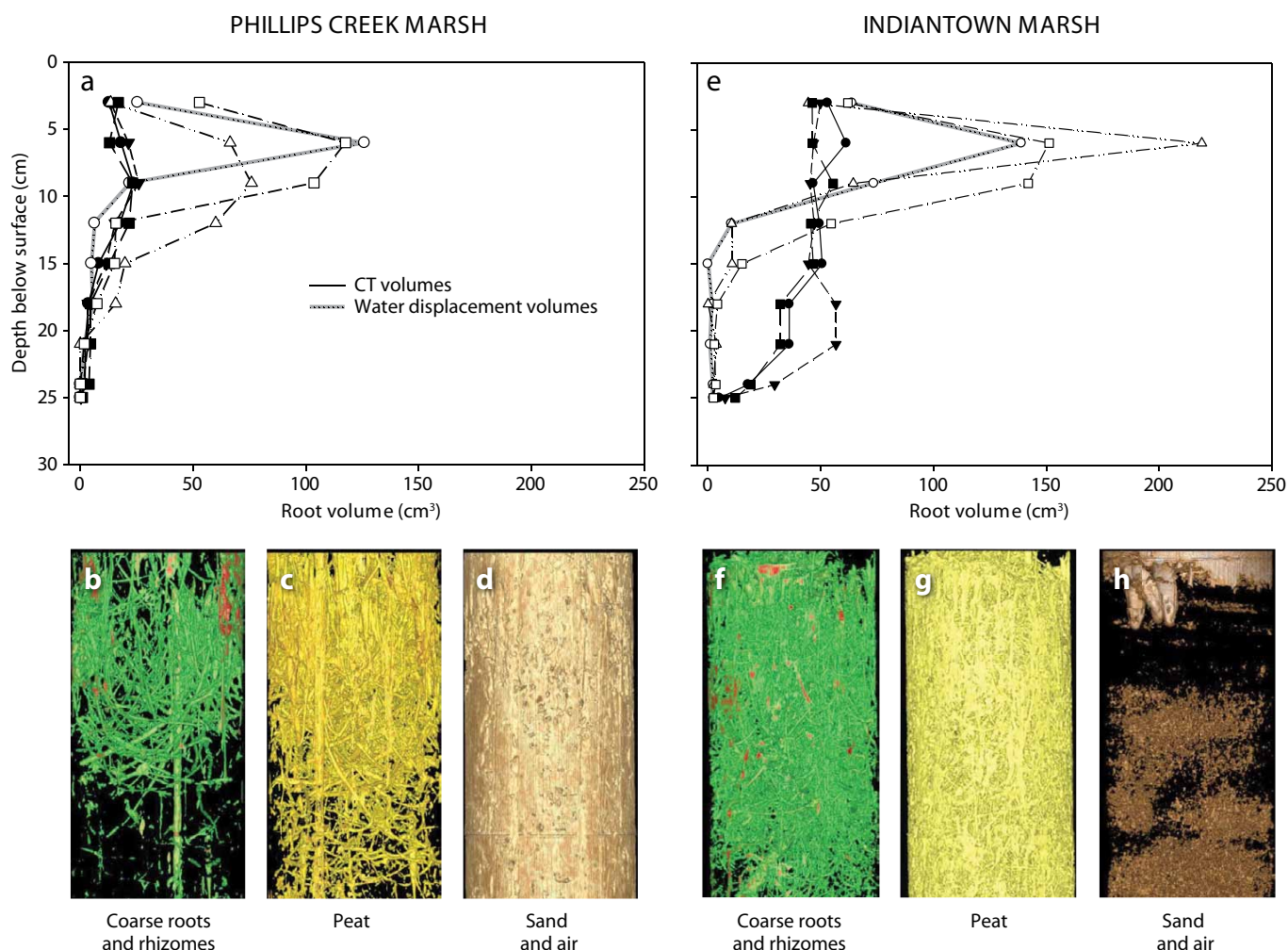
Figure 1. Comparison of root and rhizome volumes for (a) Phillips Creek marsh soil, a sandy, low-organic-matter salt marsh soil, to (e) the finer textured, high-organic-matter soil of Indiantown marsh. The distribution of root and rhizome volumes obtained by CT-imaging (solid lines, filled symbols) and displacement in water (broken lines, open symbols) is shown by depth below the soil surface. Results for three replicate cores are shown; lines with similar shaped symbols represent estimates for a single core. CT image output shows (b and f) coarse root and rhizome distributions, and (c and g) peat and (d and h) sand content of core samples collected from Phillips Creek marsh (images b, c, d) and Indiantown marsh (images f, g, h). Three mussels are visible in image h, and calibration rods are apparent in images b and c.

The soil at the Phillips Creek marsh, however, is 83% sand and contains only 5% organic matter, while the soil at the Indiantown marsh is 5% sand and 20% organic matter. CT-generated images can distinguish these soil characteristics (Figure 1c,d,g,h).

Roots and rhizomes occupy a significant volume of the top 25 cm of marsh soils, even in a highly mineral soil like that at the Phillips Creek marsh that contains 2–5% roots and rhizomes (Figure 1a,b). In contrast, the more organic Indiantown marsh soil contains 7–8% roots and rhizomes by volume (Figure 1e,f). Thus, the Indiantown marsh has nearly two to four times more roots and rhizomes than does the Phillips Creek marsh.

When the CT method was compared to the water displacement technique, the CT method underestimated root and rhizome volume in the top 12 cm at both sites where fine roots (defined as those less than one millimeter) are most abundant. Differences were especially large in the area between 3 and 9 cm below the soil surface. This lack of detection of the fine roots of *S. alternifora* by the CT method was also previously reported by Davey et al. (2011). At present, conventional medical CT scanners have a potential resolution to approximately

0.625 mm, which is not small enough to detect fine roots.

The volume of root and rhizome material estimated by the two methods was in closer agreement below 12 cm at Phillips Creek Marsh, which we attribute to the low abundance of fine roots at deeper depths (Figure 1e). At Indiantown Marsh, the overestimation of coarse roots by the CT approach below 12 cm is likely due to the misclassification of roots as living or dead by one or both of the approaches. Others have commented on the difficulties of separating live from dead roots and report data on belowground biomass as a combination of live and dead material (e.g., Good et al., 1982; Nyman et al., 1993). If CT-imaging classifies dead coarse roots that are structurally intact as living, then the CT-determined volumes should be more representative of the results reported previously by others as belowground biomass, as opposed to live roots and rhizomes.

The present CT methodology can completely budget all the volume components within a belowground marsh core, including gas, coarse roots and rhizomes, water, peat, particulates, sand, and rock and shell, as well as measure the densities of all these components. Other types of CT scanning settings and scanners are being explored that may have the resolution to detect and quantify fine roots in marsh soils. Although CT imaging currently does not detect fine roots, the advantages of the technique—that it is an objective, direct measure of coarse root and rhizome volumes that can be easily and rapidly applied to large soil cores— makes it a valuable tool for spatially and temporally intensive, comparative belowground studies.

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