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Estuarine, Coastal and Shelf Science 63 (2005) 489–496

ESTUARINE COASTAL AND SHELF SCIENCE
www.elsevier.com/locate/ECSS

Quantification of vertical density variations of salt-marsh vegetation

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Received 5 April 2004; accepted 13 December 2004

Abstract

Density and structure of salt-marsh canopies control the reduction of water flow by the vegetation, which may cause inter alia increased accretion. This paper presents and evaluates two methods that quantify the vertical density variations of salt-marsh canopies: the vertical biomass distribution and the lateral obstruction ratio obtained from a binarised picture. The former provides accurate results and is well adapted to define canopy heights; the second reflects the flow hindrance better, but is unsuitable for dense canopies. Both methods are used to illustrate density variation over short distances in *Spartina* marshes and to monitor two English salt-marshes over one year. The results demonstrate the great seasonal variability in the vegetation, which must be taken into account when long-term predictions are extrapolated from short-term measurements.

Keywords: salt marshes; vegetation density; seasonal variations; measuring methods; velocity profiles; England; the Wash

1. Introduction

Salt marshes present a great diversity in shape and density of the canopy, and also significant seasonal variations in some climates. Their canopies directly influence the water flow. Therefore, for hydrographical and sedimentological studies, an important question is how to characterise the salt-marsh vegetation (and more generally aquatic vegetation). The traditional measurements of shoot density, ground coverage, or canopy height are clearly insufficient to quantify the vegetation, because the requirements for sediment-dynamic research are different from the biological approach. The interests of the latter are mainly the plant distribution and the plant productivity (e.g., Hill, 1984; Theodose and Martin, 2003), and less the impact of the plant on its physical environment.

Satisfactory methods exist for plants with a simple morphology. For sea-grass, appropriate measures are the leaf length and the leaf area index (LAI) – ratio of the leaf area and the ground area (Gacia et al., 1999). For tall emergent plants like *Juncus roemerianus*, it is sufficient to measure the stem density and their diameters, because the water flows simply through vertical cylinders (Leonard et al., 1995). However, often the canopy is much more complex, either because the plant is composed of several parts with different shapes (e.g., stems, leaves, flowers), or because the canopy is composed of different species or individuals of different ages. In addition, comparison between different kinds of vegetation would be useful.

The "above ground biomass" is a first step to take into account all this complexity. However, there is no direct relationship between the weight of a plant and the flow hindrance it causes. In addition, the above-mentioned methods do not describe the canopy densities at the different heights, which is a key parameter for the

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doi:10.1016/j.ecss.2004.12.009

flow structure (Shi et al., 1996). Approaches exist in the recent literature to find satisfactory measurements, e.g. relative vertical distribution of plant material (Leonard and Luther, 1995).

The present paper highlights two methods: *vertical biomass distribution* and *lateral obstruction*. Advantages and limitations of the two methods for characterising intertidal vegetation are discussed. They are used here to illustrate the seasonal variations of representative English salt-marshes. These methods have been used elsewhere in the past, but are poorly known. For example, Newell et al. (1998) presented vertical distributions of dead salt-marsh biomass; Fliervoet and Werger (1984) presented vertical distributions of grassland biomass. Image analysis on lateral pictures was used to estimate characteristics of heathland and trees (e.g., Roebertsen et al., 1988; Baker et al., 1996) and it was well tested for terrestrial grassland by Zehm et al. (2003). Möller (2000) developed methods to describe the spatial distribution of vegetation using image analysis. An average measure of lateral obstruction of salt-marsh vegetation was used by Möller and Spencer (2002).

2. Methods

2.1. Vertical biomass distribution

At each survey location, several (usually three) plots of salt marsh were analysed. First, a transparent plastic cylinder (diameter 15–25 cm, height 10–15 cm) was gently placed onto the ground. The plants were clipped at the base of the stem. To avoid crushing of the plants, they were put in a very large plastic bag, which itself was placed in a large plastic box to be carried back to the laboratory.

In the laboratory, the shoots were separated. *Shoot density* can be counted at this stage. A plastic kitchen board was ruled at 2.5 cm interval (other distances adapted to the canopy could be used). The plants were placed in an approximate natural position on the kitchen board, and they were cut in segments of 2.5 cm, which corresponded to horizontal layers of the canopy. All fragments of a given layer were placed into a small, pre-weighed aluminium tray. They were dried at 80 °C for 48 h, and then re-weighed. The *total dry weight biomass* was obtained by adding together all the layers. All measurements were then divided by the area enclosed by the plastic cylinder to obtain units per square meter.

The results are weights per layer per ground unit (kg $layer^{-1} m^{-2}$). They can also be represented as percentage of total biomass per layer in order to compare relative distribution of different canopy. From the cumulative curve (Fig. 2), it is then possible to calculate by linear interpolation the heights, which include 90% or 99% of the biomass ($H_{90\%}$ and $H_{99\%}$).

2.2. Lateral obstruction

The principle was to take a lateral picture of a 10-cm thick canopy with a coloured background, and then differentiate between vegetation and background using image-analysis software.

The background was a rigid piece of plastic, markedly different in colour from the vegetation (we used red). The use of white background was not advised because of problems with shadows. Zehm et al. (2003) used a non-reflective black background (black cloth) with flash illumination to study terrestrial grassland. This colour is less adapted for intertidal vegetation, which can include very dark elements due to decaying encrusted algae. The background was inserted vertically into the canopy. A mirror was inserted vertically 10 cm away, then tilted at 45°, resting on two simple, triangular wood frames (Fig. 1). The size of background and mirror must be adapted to the canopy height. A lateral picture of the canopy was taken with a camera looking vertically downward on the titled mirror. To reduce distortions on the picture, it was best to use as long a focal length as practicable (no wide angle lens). For each picture, the mirror and the background must be clean, with the plants and the background correctly illuminated. To avoid later complication, shadows should be limited on the background.

If a non-digital camera was used, the picture was then scanned. The original picture should be larger than the background, and the preliminary operation is rotating

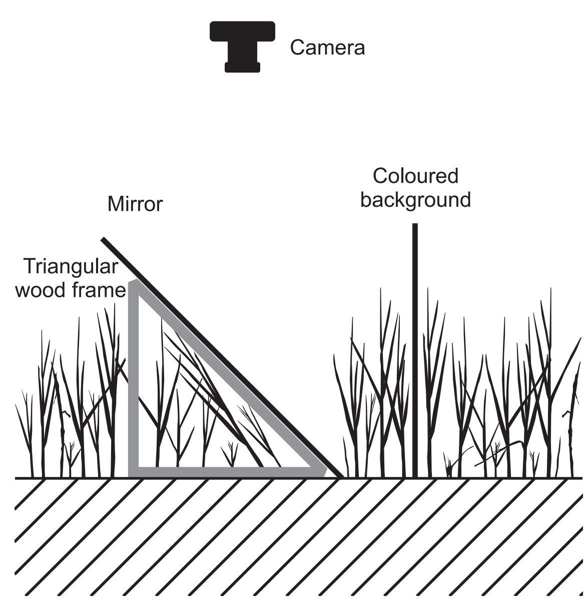

Fig. 1. Schema of the system for taking lateral pictures of a 10-cm thick canopy using an oblique mirror and a downward-looking camera.