Water Flow in Seagrass Ecosystems

by

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CANDIDATE’S DECLARATION

I declare that this thesis is entirely my own account of my research and has not been submitted for a degree at any other university.

[Signature]
Abstract

Water motion has been shown to influence almost every aspect of the ecology of seagrass communities; seagrass communities have likewise been shown to significantly influence water movement around them. This thesis examines the important role of water motion on seagrass ecosystems by integrating field and laboratory studies of several aspects of seagrass ecology influenced by water motion.

To facilitate the study of hydrodynamics of seagrass ecosystems, a solid state electronic current meter was designed and developed, using thermistors as flow sensing devices. Important characteristics of the meters include: no moving parts, compact size, high sensitivity (resolution better than ± 0.5 cm s⁻¹), and high sampling rate (greater than 0.2 Hz). Deployment of the meters in field measurements provided reliable and meaningful results of flow conditions through seagrass canopies, and they show great potential for use in many studies of marine ecology.

Field studies of water velocity profiles revealed significant differences between the shapes of profiles of different seagrass species, particularly between species of Posidonia and Amphibolis. Of particular note is the observation of a region of high water velocity beneath the leafy canopy of Amphibolis, which was not present in the Posidonia plants.

Water velocity profile measurements, sediment grain size analyses and standing stock measurements were conducted across an exposure gradient in a Posidonia sinuosa meadow. These studies revealed that, while the exposed location experienced a higher ambient water velocity than the sheltered site, the baffling influence of the seagrass canopy reduced the water velocity to approximately the same at both sites, within the meadow, although the effects varied seasonally. It was also observed that the seagrass meadow produced apparent skimming flow under the low flow conditions measured at the sheltered location; this phenomenon reflects the capacity for flow redirection over the canopy, and has important implications for the sub-canopy ecosystem and the protective role of seagrasses on the seabed.

Field and laboratory studies on the role of seagrass density on the hydrodynamic nature of seagrass ecosystems revealed that water velocity profiles through meadows of reduced densities, and different shoot arrangements, were markedly different to “natural” profiles, implying the
existence of a “critical density” (approximately 25% of natural meadow density) with regard to canopy hydraulics.

The role of water motion at an individual leaf scale was investigated with a series of laboratory flume studies of photosynthetic rates of seagrass and algae. The results show that the response of photosynthetic rate to water velocity depends very much on the plant species, with the algae markedly more productive (on a unit chlorophyll basis) than the seagrasses tested. Increases in photosynthetic rate were observed at water velocities above approximately 2.5 cm s\(^{-1}\); negligible photosynthetic activity was observed below this velocity. Calculation of P v. I curves indicated that the Posidonia species had high I\(_k\) values at low velocities (1360 μmol quanta m\(^{-2}\) s\(^{-1}\) for P. australis and 250.8 μmol quanta m\(^{-2}\) s\(^{-1}\) for P. sinuosa at 1.58 cm s\(^{-1}\)), which decreased with increasing water velocity (to 138.9 and 24.77 μmol quanta m\(^{-2}\) s\(^{-1}\) for P. australis and P. sinuosa respectively), while the algal species had relatively constant values of I\(_k\) across all water velocities (85.42 to 312.7 μmol quanta m\(^{-2}\) s\(^{-1}\) for Ulva lactuca and 169.7 to 573.9 μmol quanta m\(^{-2}\) s\(^{-1}\) for Laurencia cruciata). Dye visualization studies showed that the algae remained quite rigid at all the velocities tested, while the seagrass leaves compressed as velocity increased. This resulted in an increased rate of turbulence creation by the algae, which is believed to enhance photosynthetic rates, through improved nutrient exchange rates across the boundary layer adjacent to the thallus.

Further dye visualization studies revealed the significance of blade morphology on the creation of microscale turbulence at the surface of seagrass leaves. Epiphytic growth on seagrass leaves was observed to play an important role in breaking up water flow across the leaf surface, thereby enhancing the creation of microscale turbulence.

From these studies, it is clear that water motion influences all aspects of the functioning of all components of seagrass communities, playing a role in nutrient supply, reproduction, physical stability, temperature and metabolic functions. The influence of seagrass meadows on coastal hydrodynamics is also apparent, with potential impacts on sediment stability, recruitment of benthic species and coastal erosion. This thesis has clearly demonstrated that water motion is an important parameter in seagrass ecology, and requires serious consideration in seagrass research, conservation and rehabilitation programmes.
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