SMALL FORMAT DIGITAL AERIAL PHOTOGRAPHY FOR MAPPING AND MONITORING SEAGRASS HABITATS IN SHALLOW TEMPERATE MARINE WATERS

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and

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Dedication

To my beloved Marylyn, who glows brighter than any sun glitter could ever do…
Declaration

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

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Some parts of the thesis are either published or in the process of being published. Where there are multiple authors, the thesis only contains the portions of these works that were written by the author of this thesis. The following list indicates the components of the thesis that are either published or in the process of being published.

The majority of Chapters 1 and 2 is in press as:


A slightly adapted version of Chapter 3 is published as:


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Abstract

Seagrasses are core components of the nearshore environment and there is sustained interest in developing mapping and monitoring techniques of their extent and condition for management purposes. An identified gap in mapping methods is the capacity to monitor at landscape scales, that is, areas that are larger than the 1 m$^2$ quadrat and smaller than those covered by broad area mapping (approximately 5km$^2$ or greater). Monitoring at the landscape scale is required to investigate the dynamic patterning and patchiness present in seagrass beds, as well as providing inputs and validation for predictive modelling. However, the acquisition and use of remote sensing images for these purposes provides many challenges to the practitioner. The primary aim of this thesis is to develop effective optical remote sensing techniques for mapping and monitoring seagrass habitats in shallow temperate marine waters, over depth ranges of approximately 0-10 m and spatial scales of hundreds of square metres.

Image capture is often compromised because of environmental conditions, such as sun glitter, water clarity, cloudiness and wind. Small format digital aerial photography was selected as the remote sensing platform for its flexibility and responsiveness regarding deployment when environmental conditions are favourable and its low cost, rapid access to imagery. To address the problem of sun glitter, a simplified algorithm was developed that allows the precise prediction of the extent of sun glitter on vertical, downward-looking imagery with the readily available inputs of sun elevation angle, wind speed and sensor field of view (FOV). Subsurface illumination was also investigated via the modelling of reflection and refraction at the water surface. These improvements and investigations enable more efficient and accurate image capture. Problems are also typically encountered during image interpretation, in part due to the characteristics of the seagrass habitats, including the common occurrence of uncertain boundaries and the high variability of vegetation density. Limitations on the detectability of the maximum depth limit (MDL) of seagrass were examined, with the discovery that if imagery is captured when water clarity is higher than the annual average, the limiting factor is the contrast between the seagrass and the surrounding substrate or submerged aquatic vegetation (SAV). A simple and inexpensive measurement of water clarity, Secchi depth ($Z_{sd}$), was found to be suitable when applying this monitoring method. These findings have substantially increased the feasibility of monitoring seagrass condition and extent via the MDL, as well as the water quality parameter of average annual water clarity ($K_z$).

A major challenge for image interpretation is presented by the high attenuation of light in water, which often means that spectral methods of image analysis, such as image classification, produce poor results. In response, an improved depth correction approach
was developed that uses digital bathymetry (DEM) to assist in removing the spectral attenuation of light by the water column. The method lifted the accuracy of mapping seagrass epiphyte abundance (i.e. the amount of associated algae including epiphytic and drift algae present, related to biomass) by an average 25% to an overall average accuracy of 75%, though it made no difference to the accuracy of SAV density mapping (Note: SAV density relates to the proximity and length of the SAV blades such that high density SAV obscures the substrate and creates high levels of shadowing while lower densities have less shadowing and allow the substrate to be observed.). The improved depth correction method also enabled, for the first time from aerial photography, the production of a spatially explicit map of epiphytic biomass in the form of a continuous prediction surface with values ranging from 4 to 58 g dried weight m$^{-2}$. In response to the shortcomings of the existing field observation measurements of seagrass density and cover for image interpretation purposes, a new measurement was created, called SAV structural density or SSD, which is designed to improve thematic coherence between aerial photography and field observations, such as downward-looking benthic videography or dive quadrats. This new measurement enabled the consistent discrimination of high and low density SAV with average overall accuracies of 77%, which supports the assessment of seagrass condition, particularly when complemented by the new maps of epiphyte abundance. This thesis presents methods that improve the quality of remote sensing of shallow marine habitats and provides a more reliable basis for further investigation of habitat change detection via spatial metrics and predictive modelling at landscape scales.
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