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Abstract

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Keywords

photoreflectance, vegetation mapping

Disciplines

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Seagrass species: are they spectrally distinct?

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Abstract- The spectral reflectance of 3 species of seagrass was measured in different habitats at 3 estuaries in southeastern Australia during each of the 4 seasons of 2000. Seagrass species were spectrally distinct regardless of whether the leaves were fouled by epibionts even though spatial and temporal variability in reflectance was observed within each species. The visible wavelengths that penetrate water fortunately coincide with the regions of maximum absorption by plant photosynthetic and accessory pigments. Mapping of benthic plants to species level is possible using a hyperspectral sensor that has narrow bands centred on pigment-related spectral features in the visible, e.g. the programmable wavebands of the *casi* (Compact Airborne Spectrographic Imager).

I. INTRODUCTION

Hyperspectral image data provides researchers with the potential to map vegetation to species level, provided that the species are spectrally distinct. Differences in the spectral response of plant species can be related to differences in canopy geometry, leaf internal structure and leaf pigment content. Previous research has shown that the maximum differences in reflectance occur at the red-edge and at longer wavelengths in the NIR and SWIR [e.g. 1, 2]. Within a species, however, reflectance in these wavelength regions will vary considerably as environmental conditions impact on plant health, water status and canopy density.

Spectral reflectance differences between plant species have also been observed in the visible wavelengths (400-700 nm) [1] where photosynthetic and accessory pigments, including chlorophylls and carotenoids, absorb maximally. Aquatic and littoral vegetation have been mapped to species or community level [2, 3, 4, 5] by utilising their reflectance differences in the visible region in classifications of *casi* (Compact Airborne Spectrographic Imager) image data. Algal classes can be taxonomically identified from the absorbance features produced by their characteristic accessory pigments [6].

Remote sensing of benthic plants is limited to the visible wavelengths where light penetrates the water column. Pure water absorbs light to some extent at shorter wavelengths, however, significant attenuation of light occurs beyond 650 nm. In coastal waters, spectral scattering and absorption by phytoplankton, suspended organic and inorganic matter and dissolved organic substances further restrict the light passing

to, and reflected from, the benthos [7]. Hence, efforts to discriminate between aquatic plant species must concentrate on pigment-related spectral features within the visible wavelengths.

Seagrasses all carry the same basic complement of photosynthetic pigments; ie. chlorophylls *a* and *b*, and a range of xanthophylls and carotenoids that constitute the carotenoids. The relative concentrations of these pigments and the presence of accessory pigments vary among taxa. Genetic variation, seasonal cycles, stage of growth, health or environmental conditions can also alter pigment concentrations within a species. For example, chromatic acclimation of pigments may occur in an individual plant grown under changing conditions of water depth or clarity [8]. Spectral response in the visible wavelengths is therefore variable for a plant species over space and time. This variability may increase the chance of spectral overlap with other species. Therefore, it is important to characterise the range of signatures expected for any species under natural conditions and to determine where interspecific variation in reflectance exceeds intraspecific variation.

The aim of this study was to determine whether consistent differences occurred in the spectral response of the 3 common seagrass species of southeastern Australia, regardless of time of year, estuary or environmental situation. A further objective was to select a practical set of wavelengths for use in the remote sensing of benthic plants.

II. METHODS

The spectral response of fresh leaf samples of eelgrass *Zostera capricorni*, strapweed *Posidonia australis* and paddleweed *Halophila ovalis* were investigated once during each season in 2000. Seagrass leaves, both with and without their characteristic epibionts, were sampled from marine and brackish habitats at 3 estuaries south of Sydney, Australia (Port Hacking, Lake Illawarra and St Georges Basin). Sampling was carried out on cloud-free days wherever possible within 3 hours of maximal solar elevation. Spectral signatures were collected on a matt black background in the field using an ASD Fieldspec FR. Spectra were measured as radiance reflectance in the visible-near IR wavelengths (430-900 nm) using a 25° FOV foreoptic and a \pm 99% white Spectralon panel as the reflectance reference. Leaf samples were piled in multiple layers in order to achieve a pure signal.

A multiplicative scatter correction technique (MSC) [9] was applied to ensure that the field measured spectra could be compared on the basis of pigment content regardless of sampling date, illumination or sample geometry [10]. The standards applied in MSC were derived from the mean spectra of 30 samples for each seagrass species collected on the same date and measured under laboratory conditions.

III. RESULTS AND DISCUSSION

Clear separation was observed between the mean (\pm SD) spectral signatures for each of the 3 seagrass species in the samples measured both without (Fig. 1a), and with (Fig. 1b), the typical epibiont foulers that encrust seagrass leaves. Spectra collected from unfouled seagrass samples did not overlap at all in the wavelengths between 600-650 nm (Fig. 1a) where reflectance differences can mainly be attributed to different proportions of red, orange, yellow and brown carotenoids. At the green reflectance peak (540-560 nm) and red absorption trough (670-680 nm) the seagrass species could be separated on the basis of leaf chlorophyll content. *Z. capricorni* and *P. australis*, both absorb strongly and are distinct from *H. ovalis* at around 675 nm. *Z. capricorni*, lacks the intense green colouration of the other 2 species detected around 550 nm. In southeastern Australia the leaves of this species display a dark red or bronze colouration that apparently masks the green of the chlorophylls and may be due to the presence of anthocyanins. The minor absorption trough observed near 650 nm for *P. australis* and *H. ovalis* could indicate higher levels of chlorophyll *b* for these species than for *Z. capricorni*. It is possible that *Z. capricorni* relies less on chlorophyll *b* than *a* for photosynthesis and requires the photoprotection offered by anthocyanins because it grows at shallower depths than the other 2 seagrasses [11]. *Z. capricorni* leaves often float across the water surface at low tide while *P. australis* and *H. ovalis* leaves are only exposed during extreme low spring tides.

The seagrass species were also spectrally distinct in leaf samples encrusted by epibionts (Fig. 1b). Seagrass epibionts include a diverse array of microalgae, bacteria, juvenile macroalgae and sessile invertebrates such as tubeworms and bryozoans. These fouling organisms significantly reduced seagrass reflectance at the green peak without having a noticeable effect on the chlorophyll absorbance trough in the far red. All epibionts will mask seagrass reflectance to some degree, but it is the distinctive accessory pigments and biliproteins of algal epibionts that are responsible for the increased reflectance peaks observed between 560-670 nm.

Although leaf epibionts are not host specific, certain taxa may be associated with particular seagrass species because of blade size and shape, and leaf turnover time [12]. For

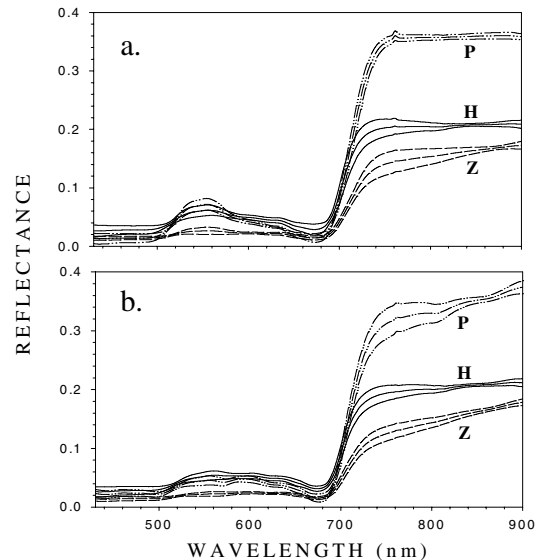


Fig. 1. Mean \pm SD spectral reflectance of 3 southeastern Australian seagrass species a. without, and b. with leaf epibionts (P = *Posidonia australis* n=80, H = *Halophila ovalis* n=90 and Z = *Zostera capricorni* n=220).

example, coralline algae (and a high diversity of other fouling organisms) typically cover more than 80-90% of the surface of mature *P. australis* leaves because the blades are large and long-lived. The influence of such heavy fouling on the green reflectance peak of *P. australis* is evident in Fig. 1b. In contrast, the small, soft leaves of *H. ovalis* support low densities of only a few epibiont species and therefore retain much of their green reflectance.

In many coastal waters light penetrates significantly in the 480-630 nm range. Fig. 2 shows seagrass reflectance in relation to the spectral light attenuation by an estuarine water column of 2.1 m. Although large differences in NIR reflectance between species exist for both fouled and unfouled seagrass samples (out of the water), this wavelength region will only be useful for remote sensing emergent or exposed plants. In the blue wavelengths, remote sensing of benthic vegetation is impractical because sensor sensitivity is usually low, atmospheric effects are large and algal pigments, organic matter and detritus all absorb light.

IV. CONCLUSIONS

The optimal wavelengths for the discrimination and mapping of seagrass meadows to species level in coastal waters lie between 500-630 nm as well as in the somewhat attenuated wavelengths between 630-680 nm. An appropriate hyperspectral bandset for the remote sensing of seagrasses should include narrow bands (maximum 5-10 nm

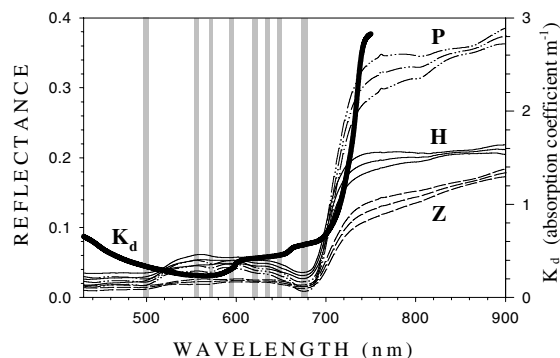


Fig. 2. Relationship between spectral absorption (K_d) by an estuarine water column of 2.1 m and the mean \pm SD spectral reflectance of 3 seagrass species (P, H and Z) with leaf epibionts. The grey bars indicate suggested locations of wavebands for the remote sensing of benthic vegetation.

bandwidth) centred around:

1. one or two regions of good separation between species in the absorption troughs and reflectance peaks of the seagrass photosynthetic and accessory pigments, e.g. 555, 635, 650 and 675 nm.
2. at least one region where separation between species is poor as a reference wavelength, e.g. 500 nm.
3. 1 or 2 regions of pigment absorption or reflectance by algal epibionts for situations where fouling of the seagrasses is a persistent feature of the natural seagrass meadows, e.g. 570, 595 and 620 nm.

The specific selection and placement of narrow bands requires a programmable sensor such as the *cas*i. As this airborne hyperspectral sensor also provides image data of high spatial resolution, it has proven to be well suited for mapping the often small and patchy seagrass meadows that occur in southern Australia [4, 5]. Fixed band sensors such as HYMAP, AVIRIS and HYPERION (with bandwidths of 15 nm, 9 nm and 10 nm respectively) will perhaps be less suitable unless their band positioning coincides with the relevant spectral features, despite the large number of bands they offer. Hyperspectral image data sets could be considerably reduced in size by more careful selection and placement of wavebands.

The pigment-related spectral differences between the 3 species investigated here appear to be independent of time of year, location or environmental conditions. Although reflectance differences were observed within the spectral response of each seagrass species, intraspecific spectral variability was relatively small in comparison to interspecific reflectance differences.

It is therefore possible to map meadows of different species of seagrass using hyperspectral imagery. The

wavelength region in which light penetrates to the maximum depth through water coincides with one of the optimal regions for the detection of plant pigment content. A further challenge for researchers lies in relating the spectral response of leaf samples to real mapping situations where the canopy geometry of the seagrasses, substrate type, overlying water column composition, as well as air/water interface effects and the atmosphere, must also be taken into account.

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