HYPERSPECTRAL IMAGING AS A TOOL FOR CAMOUFLAGE EVALUATION OF THE SARGASSUM CRAB *PORTUNUS SAYI*

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Introduction

Biological camouflage has evolved in multiple phyla as an adaptation to visually-orienting predators. Spectral camouflage, or color matching, is common in the marine environment (Hacker and Madin 1991, Hanlon et al. 2009). How effectively an organism is able to match its background is largely dependent upon the visual system of the observer. Due to the vast array of biological photoreceptors found in the oceans, evaluating camouflage solely from the point of view of human optical response is insufficient (Endler 1990). Hyperspectral imaging (HSI) captures a digital image with full spectral information for every pixel, and is an invaluable tool for the objective study of spectral camouflage (Chiao et al. 2011).

Floating *Sargassum* provides a critical habitat in the open ocean, which many organisms utilize for at least a portion of their life cycle. A *Sargassum* mat is an extremely complex optical and structural environment, and many of its associated fauna display some form of camouflage (Hacker and Madin, 1991). The crab *Portunus sayi* has a yellow/brown, mottled appearance which blends well with its macroalgal background. Adults of the species display varied pattern and shading, and individuals may be capable of altering both attributes over a matter of hours (Fig 1).

Figure 1. *P. sayi* displaying color variations typical of the species. Separate individuals are shown with samples of *Sargassum* sp.

METHODS

Data was collected during May of 2011 aboard the *SSV Corwith Cramer* in the eastern Gulf of Mexico. Clumps of *Sargassum sp*. (*fluitans* and *natans*) were collected using fine mesh dip nets.

Image cubes were collected with the 710 Hyper Spectral Imager (Surface Optics Corp.) under daylight (zenith) illumination with a diffusive, black background. A 99% reflectance standard was included in every frame (Fig. 2). Samples were imaged both in air and in filtered seawater. Resultant data cubes were analyzed using software provided with the instrument and ENVI (ITT Visual Information Systems). To compensate for differences in lighting and water column effects between cubes, reflectance values were calculated using the in-frame standard.

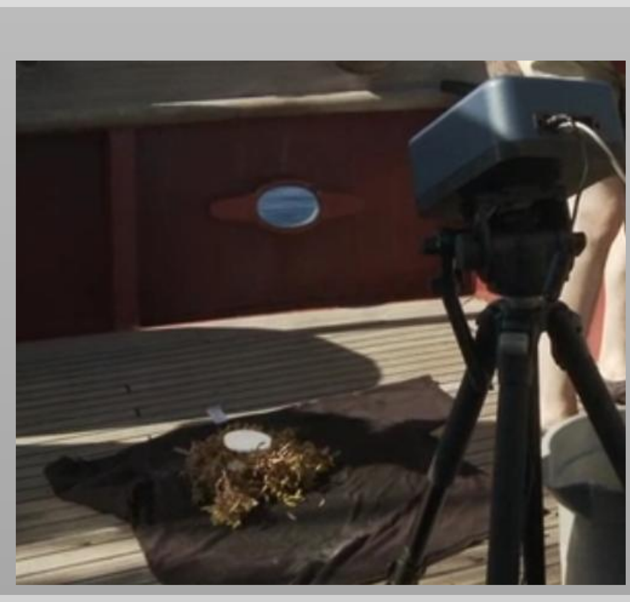

Figure 2. Field set-up for imaging of animal and algal samples.

Results

Portunus sayi appears extremely well hidden in *Sargassum* to human eyes (Fig 3). The shape and magnitude of the crab's reflectance curve is very similar to that of the macroalgae in the blue, green, and yellow regions of the spectrum, with greater divergence appearing in the red. The largest difference in magnitude is observed in a small region centered around the secondary chlorophyll absorption peak (Fig 4). Monochrome images created from data at single wavelengths illustrate the crabs' reflectance matching abilities (Fig 5).

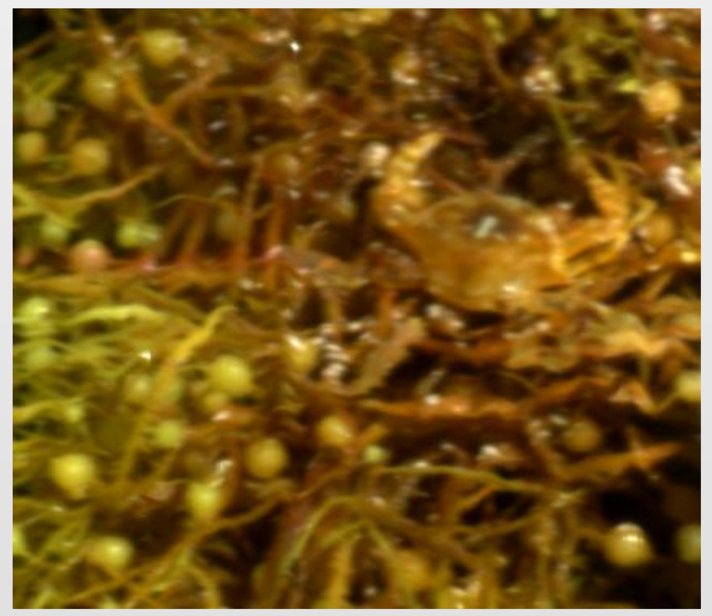

Figure 3. Pseudo-true color image created from HSI data, utilizing RGB channels at 432, 532, and 582nm.

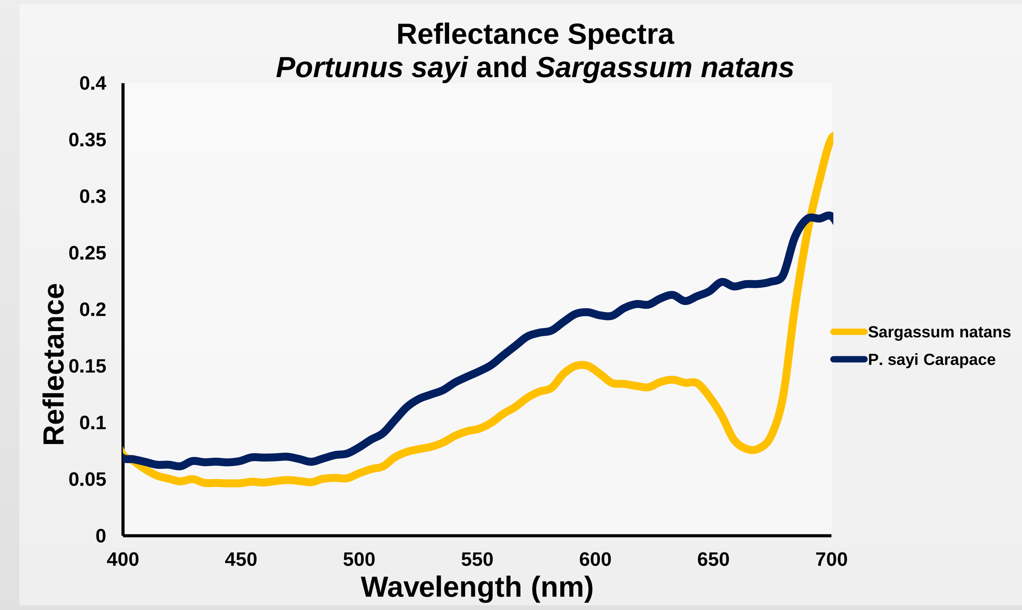

Figure 4. Crab and macroalgae reflectance curves. Crab spectrum represents an average of carapace pixels, while algae curve was generated from an equal number of randomly located *Sargassum* pixels.

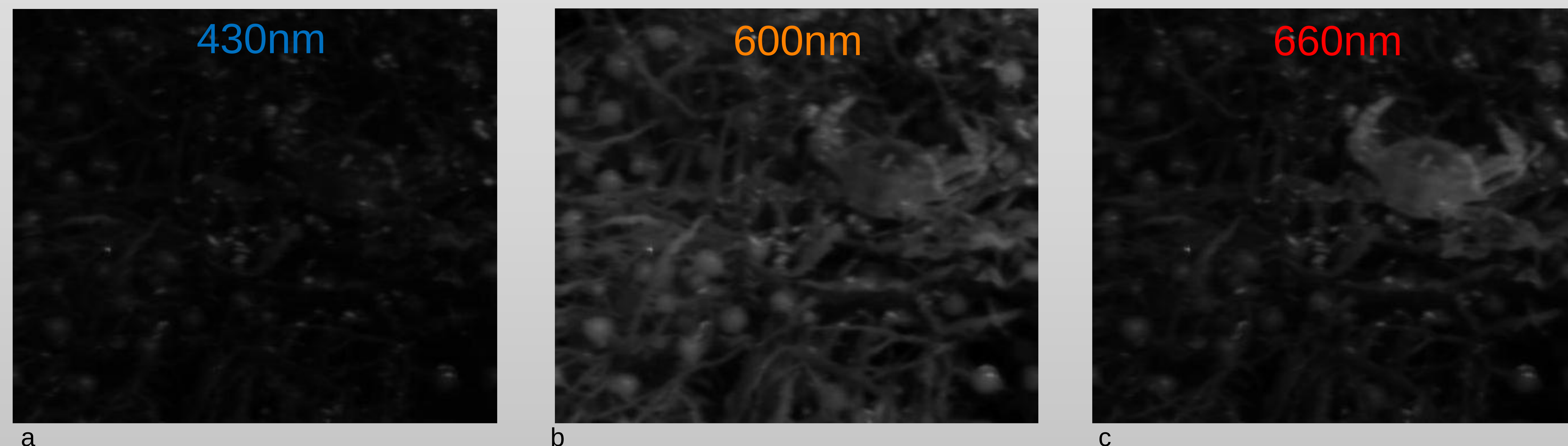

Figure 5. Monochrome images derived from HSI data at 430, 600, and 660nm. These wavelengths represent spectral regions where both crab and *Sargassum* are (a) highly absorbing, (b) reflective, and (c) the region of maximum contrast between *P. sayi* and its background.

Reflectance data was analyzed using ENVI software. Image classification techniques (Principal Component Analysis (PCA), Spectral Angle Mapping (SAM), k-means unsupervised) have difficulty separating crabs from macroalgae. Success can be achieved with PCA (Fig 6) and SAM (Fig 7), but only if far-red data is included. k-means classifications showed a high degree of matching between crab and macroalgae even with full spectral data (not shown).

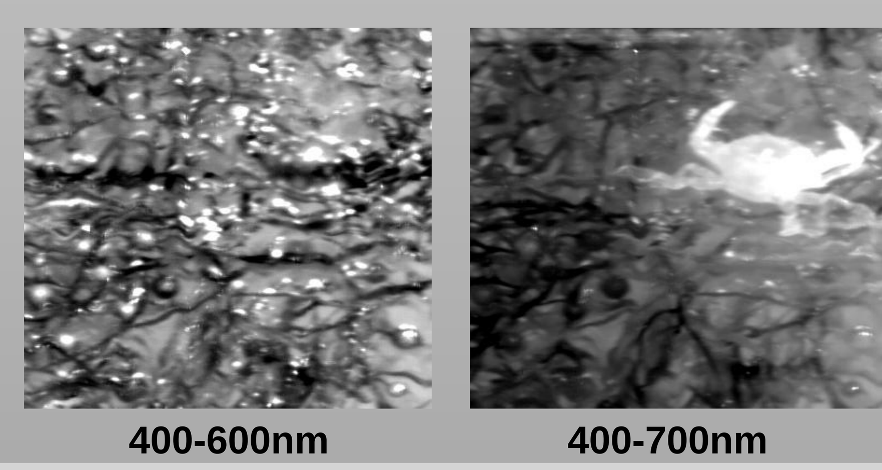

Figure 6. Principal Component Analysis of HSI data. PCA indicated the crab as a distinct source of spectral variance within the cube only with the inclusion of far-red data. The second component is displayed, as the first component in both spectral ranges was due to artifacts of data collection.

Figure 7. Spectral Angle Mapping of HSI data using different spectral windows. Average carapace reflectance was used as an end-member. SAM only clearly differentiated between crab and macroalgae when far-red (>650nm) was included.

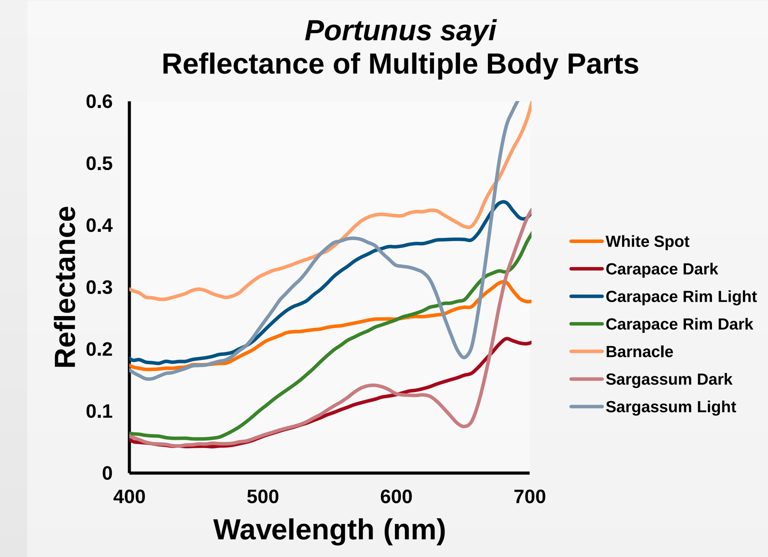

Figure 8. Reflectance values for several locations on *P. sayi*, with values for components of its habitat.

Neither *P. sayi* nor *Sargassum* are uniform in color. The shape and magnitude of reflectance differs across the crab's body. These differences, as well as the varying spectral characteristics of the *Sargassum* habitat and potential relevance to camouflage, are being investigated (Fig 8).

Crab color features and patterning may assist in camouflage to varying degrees, depending on spectral region. Highly reflective portions may mimic barnacles and other *Sargassum* epibionts within the visual range of common *P. sayi* predators. Preliminary kurtosis measurements indicate patterning in both crab and macroalgae vary with wavelength.

Future Work

The ability of *P. sayi* individuals to match the varying color forms of pelagic *Sargassum* will be evaluated through behavioral experiments. Crab pigments will be evaluated with HPLC and compared to algal and animal pigments found within *Sargassum* mats.

Camouflage is heavily dependent upon the observer, and so the visual receptors of *P. sayi* and its known predators will be investigated for spectral response and polarization sensitivity. This information can then be compared to polarized spectral reflectance data for crab and algae, and measurements of the light field within *Sargassum* mats.

The techniques used here are being applied to other camouflage scenarios. Full spectral data of flounder, killifish, and terrestrial katydid insects indicate that some species which camouflage against a photosynthetic background may exhibit far-red spectral shape similar to the photosynthetic pigments.

This work will form the basis of the corresponding author's doctoral dissertation.

Literature cited

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For further information

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