

# Exploring the Utility of the Broadband Multispectral Sensor WorldView2 for Investigation of Nearshore Coastal Environments\*\*

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**Abstract - Utility of the Worldview2 (WV2) sensor was examined for mapping and quantifying submerged aquatic habitats along the Florida Gulf Coast. Benthic types ranged from bare sand to dense seagrass. Satellite imagery was atmospherically calibrated using co-incident ground based measurements of  $R_{rs}$ . Sand and seagrass were distinguished by brightness in the green (510 to 580 nm) band. Bottom reflectance ( $R_b$ ) for each sand and seagrass pixel was retrieved using a radiative transfer approach that removed the filtering effects of the overlying water column. Seagrass abundance was then calculated using an empirical relationship between  $R_b$  in the green and LAI. Characteristics of the sensor requires independent knowledge of water depth and benthic optical properties in order to quantify these benthic habitats, however once these properties are known successive images can be processed without the need for further *in situ* collections.**

**Keywords: seagrass mapping, optically shallow habitats, radiative transfer**

## 1. INTRODUCTION

Seagrasses form extensive meadows in shallow coastal environments throughout the world, where they provide a number of critical ecosystem services, including a source of organic carbon, habitat for numerous species of fish and invertebrates, sediment stabilization and shoreline protection (Gillanders 2006, Marbà et al. 2006). Despite the environmental and economic significance of these “ecosystem engineers”, seagrass populations are threatened world-wide by coastal development and anthropogenic eutrophication (Short & Wyllie-Echeverria 1996). Decline in seagrass habitats has occurred throughout the world, and may be nearing a crisis with respect to global sustainability (Orth et al. 2006). Reliable methods for landscape-scale assessment of seagrass distributions are needed to manage this critical resource in the context of coastal biogeochemical processes and changing ocean climate. In particular, the long term management of seagrass habitats depends on accurate and quantitative measurements of areal coverage and bed density. Hyperspectral imagery can be useful to identify and map submerged aquatic vegetation (SAV) in optically shallow coastal environments using differences in spectral reflectance between SAV, sand and optically deep water targets (Dierssen et al. 2003), but systems to provide these data are not readily available. Our objective was to investigate the utility of mapping SAV from the WorldView2 (WV2) orbiting sensor operated by Digital Globe, LLC. This sensor provides radiometrically calibrated imagery (11-bits dynamic range) in 8 spectral bands from 400 to 1050 nm at 3 m spatial resolution.

## 2. METHODS

A field campaign to validate WV2 imagery for benthic habitat characterization was conducted in collaboration with the Florida Department of Environmental Protection along the coastal region of Taylor County, FL, USA, from 14 to 29 May 2010. During this period, a digital elevation model (DEM) of the study region was generated from a multibeam acoustic survey conducted during the field campaign. Diver surveys characterized bottom type (bare sand vs. seagrass) measured seagrass LAI when present and measured  $R_b$  using randomly located quadrats at each station. Water column optical properties ( $a$ ,  $b$ ,  $c$ ,  $b_b$ ,  $K_d$ , VSF) were measured using an *ac-9+* pkg (Wetlabs, Inc.), HydroScat-6 (HOBI Labs, Inc.), LISST (Sequoia Scientific, Inc.) and HyperPro profiling radiometer (Satlantic).

A WV2 image of the region was acquired on 20 May 2010. Atmospheric correction was performed using TAAFKA and ground-based based estimates of  $R_{rs}$  derived from water column irradiance distributions, inherent optical properties and apparent optical properties measured at 12 stations across the study area, using the instrument systems described above.

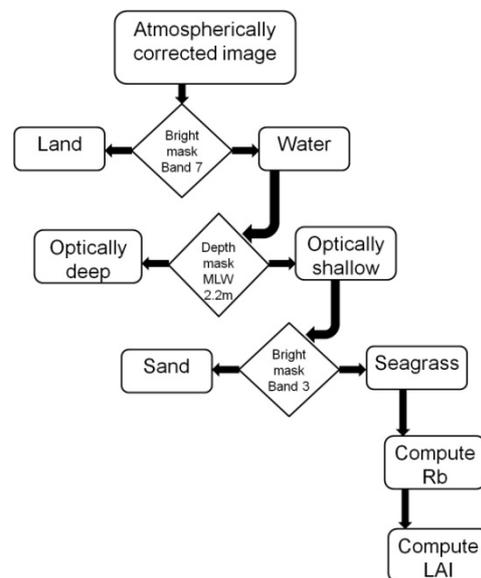


Figure 1. Processing algorithm for deriving seagrass LAI from WV2 imagery.

The atmospherically corrected image was then processed for quantification of seagrass LAI using an algorithmic approach (Figure 1). Land and water pixels were separated based on the brightness (magnitude) of MS1(NIR 1, 770 –

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895 nm, Figure 2). Water pixels were then separated into “optically deep” and “optically shallow” using a geometric depth criterion (2.2 m) derived from radiative transfer calculations using optical properties measured *in situ* across the region. Optically shallow pixels were then separated into “sand” and “seagrass” based on the brightness of Band MS3 (green, 510 – 580 nm). Bottom reflectance ( $R_b$ ) was then calculated for each seagrass pixel by inverting  $R_{rs}$  using the DEM and measured water column optical properties (Dierssen et al. 2003). Seagrass LAI values retrieved from the WV2 imagery were validated against diver-measured LAI values at the station locations.

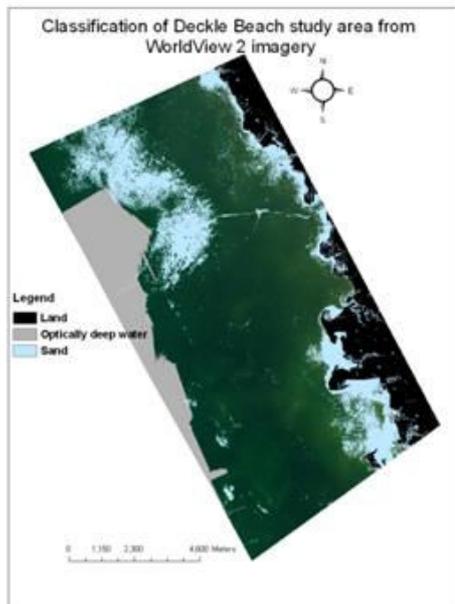


Figure 2. Atmospherically corrected WV2 image (RGB) of Taylor Florida study region, with masks for dry land (black), optically deep water (grey) and bare sand (aqua) applied. The remaining pixels (shades of green) represent seagrass.

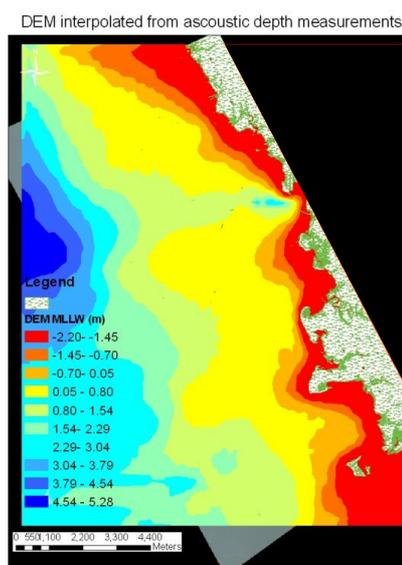


Figure 3. Digital elevation model of submarine bathymetry derived from multibeam acoustic survey of the study area.

### 3. RESULTS AND DISCUSSION

The digital elevation model was derived from the acoustic soundings using an inverse distance weighting interpolation scheme in ARC-GIS. A shoreline polygon was created from the land mask raster data and assigned a depth of 2.2 m above MLW (depth is positive down (Figure 3)). The submarine bathymetry of the region slopes gently away from the shoreline. A dredged navigation channel for recreational boat access to Deckle Beach represents the major bathymetric feature. Mean depth across the study region was 1 m.

The spectral peaks and shoulders that are characteristic of sand, seagrass and algae reflectance are often distinguishable with 5 nm resolution available from hyperspectral data. Unfortunately the broader MS2 (red) and MS3 (green) bands of WV2 do not provide sufficient spectral resolution to distinguish among the subtle spectral features representative of different marine taxa (Figure 4). However, spectral resolution and dynamic range of these visible bands are sufficient for distinguishing submerged aquatic vegetation from sand.

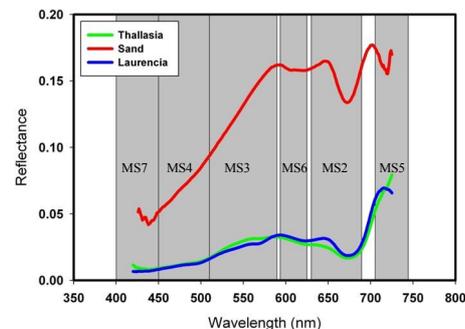


Figure 4. Characteristic spectra of seagrass (*Thalassia testudinum*), a red seaweed (*Laurencia* sp.) and bare sand collected using a diver-operated spectroradiometer mapped across the visible bands of WV2. NIR Bands MS1 (770 – 895) and MS8 (860 – 1040) are not shown.

The WV2 instrument is tuned to account for the bright reflectance in the NIR from land, which was three orders of magnitude greater than that over water (Figure 5).

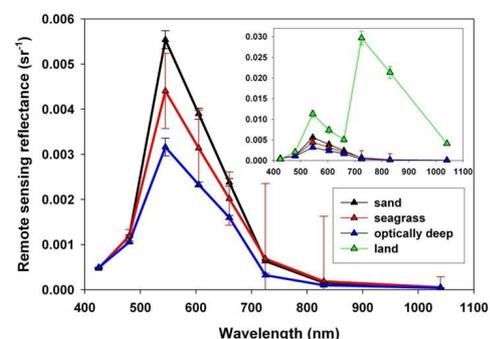


Figure 5. Representative  $R_{rs}$  spectra retrieved from WV2 over dry land (inset), seagrass, bare sand and optically deep water. Error bars represent 1 standard error in  $R_{rs}$ .

Unfortunately the 11-bit resolution renders bands MS1 (IR1) and MS8 (IR2) of little utility for shallow water environments. However, bands MS4 (blue), MS3 (green) and MS6 (yellow) possess enough sensitivity to be useful for investigating shallow water pixels. The bright green  $R_{rs}$  of bare sand was easily distinguished from the darker reflection from SAV and optically deep water. Optically deep water and SAV were more difficult to separate, due to overlap in all bands. Modeled  $R_b$  was consistent with observations (Figure 6, c.f., Figure 4). Further green reflectance (MS3) decreased as SAV density increased because the dark vegetation blocked reflectance from the brighter sand beneath the canopy.

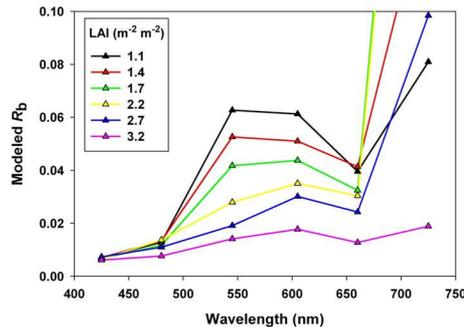


Figure 6. Bottom reflectance ( $R_b$ ) retrieved from WV2 imagery for different seagrass densities.

Remotely sensed retrievals of seagrass LAI derived from  $R_b$  of MS3 (green) compared favorably with direct measurements performed by divers. The slope of the relationship (0.9734) was not significantly different from 1, and explained 71% of the variation across the observed stations, including bare sand (Figure 7).

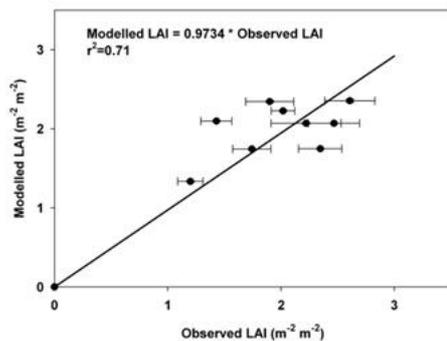


Figure 7. Relationship between LAI measured by divers at ground stations and remotely sensed retrievals.

The resulting map of SAV density across the study region (Figure 8) revealed a complex pattern. In general the region was densely vegetated. Highest densities ( $LAI > 2$ ) occurred in the southern part of the study area in water depths between 1 and 2 m MLW. A gradual decline in seagrass density was observed as water depths increased approaching the bare sand patches in the northeast portion of the study area. Overall, submerged and emergent (intertidal) vegetation covered  $74 \text{ km}^2$  (80%) of the aquatic habitat in this study area. Bare (unvegetated) sand covered  $7 \text{ km}^2$  (7%) of the area, and optically deep water covered

$12.5 \text{ km}^2$  (13%), mostly along the offshore edge of the study area.

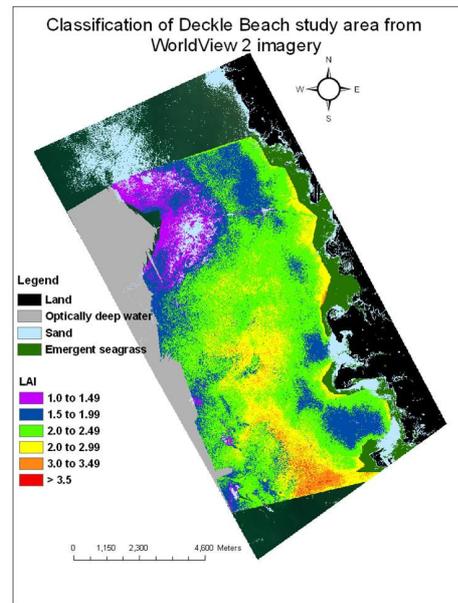


Figure 8. Classification map of seagrass density across the Taylor County/Deckle Beach study area.

Prop scars and other small features were not identifiable in the 3 m multispectral imagery, but can be clearly seen in the higher spatial resolution (0.3 m) panchromatic imagery. An algorithm for characterizing these small scale features from the panchromatic imagery is under development.

#### 4. CONCLUSIONS

The broad bands of WV2 offer the ability to discern between bright sand and dark SAV targets. The dynamic range of blue, green and yellow are sufficient for quantification of SAV abundance in optically shallow waters and high spatial resolution of WV2 provides the necessary scale to observe the heterogeneous and patchy nature of SAV meadows. Unfortunately, bands characterizing the red edge and NIR regions needed for discrimination of depth, optically deep water and algae vs. seagrass do not appear to have sufficient dynamic range for analysis of optically shallow environments. Inability to retrieve water depth from the imagery makes *a priori* knowledge of water depth necessary.

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