Spectral classifying base on color of live corals and dead corals covered with algae

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Abstract

Pigments in the host tissues of corals can make a significant contribution to their spectral signature and can affect their apparent color as perceived by a human observer. The aim of this study is classifying the spectral reflectance of corals base on different color. It is expected that they can be used as references in discriminating between live corals, dead coral covered with algae Spectral reflectance data was collected in three small islands, Spermonde Archipelago, Indonesia by using a hyperspectral radiometer underwater. First and second derivative analysis resolved the wavelength locations of dominant features contributing to reflectance in corals and support the distinct differences in spectra among colour existed. Spectral derivative analysis was used to determine the specific wavelength regions ideal for remote identification of substrate type. The analysis results shown that yellow, green, brown and violet live corals are spectrally separable from each other, but they are similar with dead coral covered with algae spectral.

Keywords: Hyperspectral, derivative, live corals, dead corals, algae

1. INTRODUCTION

Background

Coral reefs are most biodiverse marine ecosystem of the world. The characteristic variety of colors seen within the living benthic components of a coral reef is mainly due to the array of photosynthetic and photoprotective pigment present in the cell of them [27]. Knowledge on the spectral separability of benthic communities is useful for designing and optimizing coral reef remote-sensing applications [1]. The spectral library presented may provide the opportunity for reliable classification of submerged coral reef ecosystems thus reducing the cost of the monitoring project. It may also aid scientists and managers using remote sensing in selection of optimal band location and bandwidth characteristics. Spectral response of coastal benthic communities could substantially improve mapping accuracy of coral reefs maps when applied in remote sensing image classification.

Optical signatures of corals and other coral reef benthic types collected in different parts of the world [18], [23], [3], [8], [9], [10], [11], [12], [19], [14], [15], [16], [26], [1], [4], [17], [5], [6], [7], [13], [20], [25] show that the shapes of reflectance spectra of live corals, dead corals, sand, seagrasses, green, brown and red algae are consistent in different locations of the world. This suggests that a classification of remote sensing imagery based on the optical signatures of different benthic types should be applicable in different locations of the world even if no field data is available.

The benthic communities of the Spermonde archipelago, Indonesia are characterized by a high biodiversity. [28] reported that there are over 400 different species of hard coral alone. Thus, a large and comprehensive spectral library of substrate types is needed in order to resolve the spectral variability found in the Spermonde archipelago, Indonesia. Spectral measurements using a radiometer were done for the first time in Manado, Indonesia [11]. They measured spectral reflectance of typical coral reef features including healthy branching coral, healthy massive coral, bleached coral, algae-covered surfaces, dead coral debris and sand substrates. Using *in situ* reflectance data we extent the work to examine whether live corals can be spectrally discriminated from dead corals with algae colonisation.

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Although remote sensing technologies have great potential in overcoming this quantitative void, there are many complications associated with extracting valuable information from imagery with confidence. One problem with remotely sensed measurements is that the atmospheric path between object and sensor will modify characteristics of the radiation signal at the sensor. The air-sea interface contributes to a second complicating factor since the amount of energy transmitted into the sea versus that reflected off the surface depends on sea surface state, wind speed and sun angle.

Objectives

The objective of this study is classifying the spectral reflectance of corals base on different color as optical properties of the live corals and dead corals covered with algae in small islands, Spermonde archipelago, Indonesia.

2. METHODOLOGY

Study area

Spermonde archipelago consist of over 100 small islands that have valuable marine resources and extremely rich ecosystems [21]. Spermonde archipelago, known by the public as Sangkarang is Located in the Makassar Strait, southwest of the peninsula of Sulawesi. Some coral reefs at the outer boundary of Spermonde at a shallow area called Spermonde Barrier Reefs. Spermonde archipelago is divided into four zones base on the distance from main island and depth. The first zone or the most superficial zone, parallel to the shoreline with a maximum depth of ± 20 meters. The second zone starts from ± 5 km of coastline with a depth of ± 30 meters. The third zone starts from 12.5 km to the off-shore with a depth of ± 30-50 m. The fourth zone or outer zone or barrier reef zone begins from a distance of about 30 km from the coast of main land and a depth more than 40 m. Spermonde archipelago climate is tropical. The rainy season from December to March and the dry season from May to October. Three small islands on the Spermonde archipelago, South Sulawesi, Indonesia, were selected to measure the reflectance spectral of live and dead corals. Spectral measurements were conducted in Barrang Lompo island, Barrang Caddi island, and Badi island on 15 to 22 June 2014 under generally clear skies.

Coral Sampling

A Global Positioning System provided geographic and an underwater photographer identified and took a picture of each target measured for future reference. The dataset includes 69 spectra of live corals and 60 spectra of dead corals representing live and dead corals covered with algae. The total number of substrates for which reflectance spectra were collected was 129. We studied the optical properties of the *in situ* measured coastal benthic communities and devided the substrates into the following classes: live corals and dead corals covered with algae. Coral sampling using Lambda NIR portable field spectroradiometer (Figure 1).

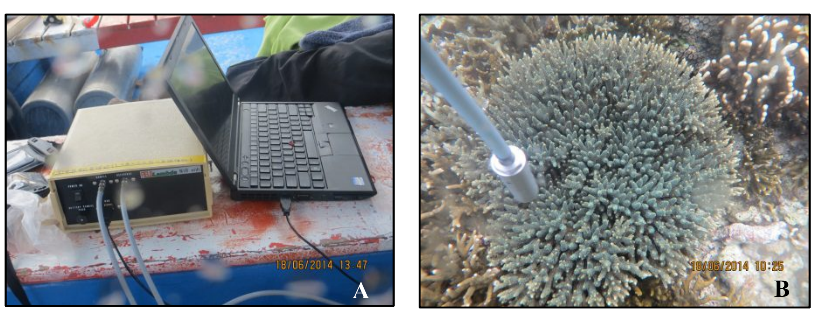


Figure 1. The Instrument: (A) Spectrofotometer Field Lambda NIR enh on boat with a spectral range 350-1000 nm, (B) Underwater sensor measure reflectance above a live coral

The reflectance spectra were taken over each sample between 2 and 5 meter, and each spectrum was the result of averaging of individual scans compiled over approximately 30 seconds. Spectral data was collected in situ between 9:00 a.m. and 15.00 p.m. local time, when the sun is high in the sky. The sensor enclosed within custom for underwater that has a spectral range of 350 – 1000 nm. Sample from Spermonde archipelago shallow water objects. Depending of availability, 15-20 samples were collected from each of the four live corals species and dead coral covered with algae. In some cases reflectance spectra of live and dead corals covered with algae were measured on board the boat immediately after collecting the substrates. To achieve a pure signal, leaves were piled on matt black background in multiple layers [22].

Live and Dead Corals Spectral Collection

We select coral reef area having high heterogenety by using manta towing tecniques and determination of station points. The manta tow technique is useful for selecting sites representing a large areas of reef [24]. Dark measurements taken in each experiment were used to subtract additional operational noise. A calibrated white reference standard was used following each sample measurement, placed at the exact location and height of the sample. Spot measurement of individual substrate types were made from about 2-5 cm above the substrate, resulting in a field of view of about 1.5 cm. Each measurement took about half a minute, capturing over one hundred spectra. The objective of taking live and dead corals spectral measurements of the reef substrate is to characterize spectral features of various components, so the sampling strategy was to measure the spectral response as many features as possible. A 15 meter fiber-optic cable links the spectrometer to the sensor head, which was fitted with a remote cosine receptor with a hemispherical field of view (FOV). The advantage of the submersible remote cosine receptor is that it enables a SCUBA diving operator to measure substrate reflectance just above the target, so measures are representative of the feature without the attenuating affects of the water column. The instrument was held at a nadir angle approximately 7 cm above each feature of interest, and a photograph was taken to accompany each suite of measurements for given target. Since the sensor was held above the target, the water column between the sensor and the target is assumed to be negligible, so no correction for attenuation was performed. Furthermore, no radiometric calibration of the spectral data was necessary, as the values used in the analysis is reflectance values.

Spectral Derivative Analysis

Derivative spectroscopy uses changes in spectral reflectance or radiance with respect to wavelength to sharpen spectral features. Derivatives allow components of the spectrum to be more clearly separated. This method was used here which gives the approximation of the first derivative at the midpoint between the spectral values used. The first order derivative provides information on the rate of change in reflectance, which is the slope, with respect to wavelength, while the second order derivative reveals the change in slope with respect to wavelength.

3. RESULT AND DISCUSSION

Spectral Characterization of Live Corals and Dead Corals Covered with Algae

The benthic communities in Spermonde Archipelago were as follow: live corals and dead corals covered with algae. While there were differences in magnitude, all live corals species showed the typical reflectance peaks around 575-580 nm eventhough dead coral covered with algae. In the present study the live corals were divided into four color (light green, brown, green and yellow) based on visual classification (Figure 2) and dead corals covered algae were divided into four color (brown, green, light green and violet) in Figure 3.

All of the measured parts of the live corals appeared similliar in spectral magnitude and shapes. Its reflectance was generally lower in the shorter wavelength region (425) nm, peaked around 575-580 nm and steep a rise around 700 – 725 nm. Light green live coral display measured spectra with reflectance minimal at 450 nm and its peak reflectance at 580 nm. measured spectra with reflectance minimal at 450 nm and peak reflectance at 575 nm. display measured spectra with reflectance minimal at 450 nm and peak reflectance at 575 nm. measured spectra with reflectance minimal at 450 nm and peak reflectance at 575 nm. The average maximum reflectance values of live corals were between 0% - 25%, green live coral has the highest reflectance value (25%) meanwhile brown live coral has the lowest reflectance value (0,2%). With the same similliar reflectance on this live corals cateory it is indicated that it's couldn't be easily to separated these corals based on its specifif colors.

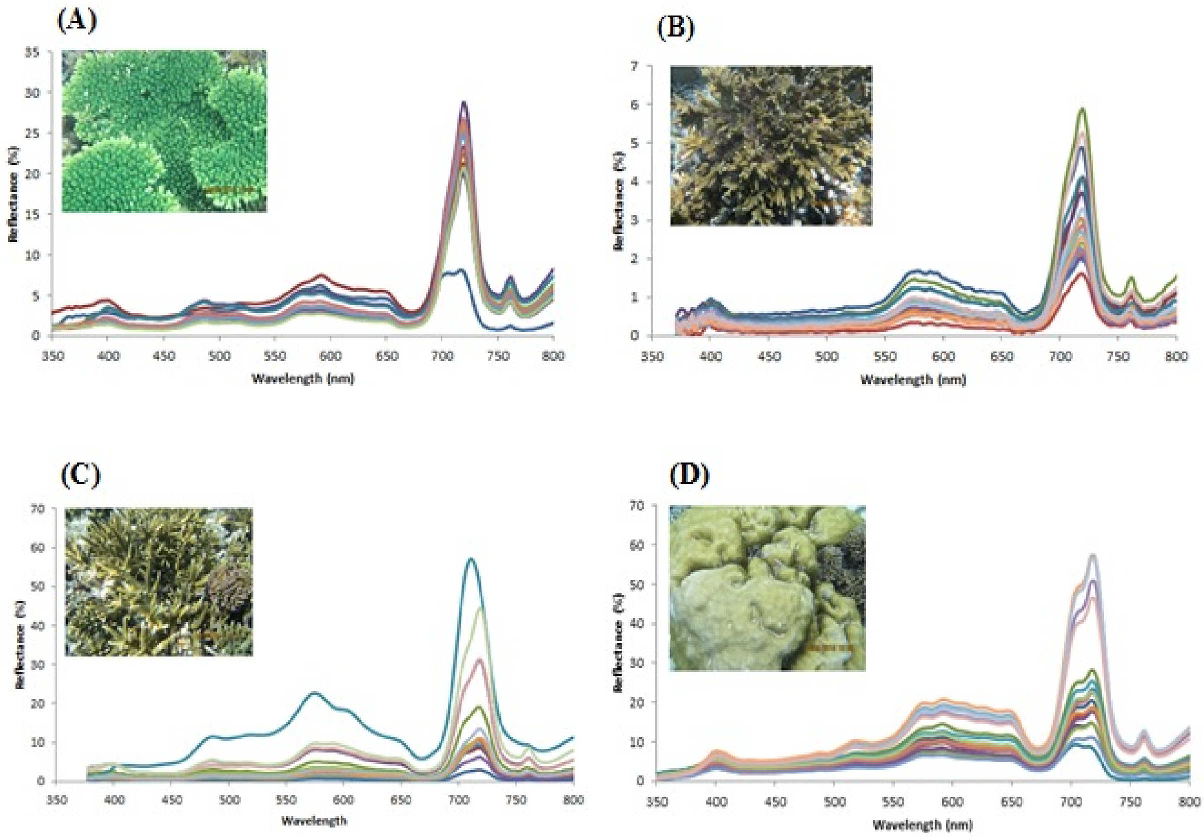


Figure 2. Reflectance spectra of live coral category. (A) light green live coral, (B) Brown live coral, (C), Green live coral, and (D) yellow live coral.

Dead corals covered with algae category also has simmiliar spectral magnitude and shapes (Figure 3). Its lowest and peak reflectance shows as similiar as live coral category (around 575-580 nm). Dead coral covered with violet algae has the highest reflectance value (28%) than any other dead corals categories and dead coral covered with light green algae has the lowest reflectance value. It was somewhat more difficult to distinguish reflectance differences between these dead corals when the corals were covered with algae.

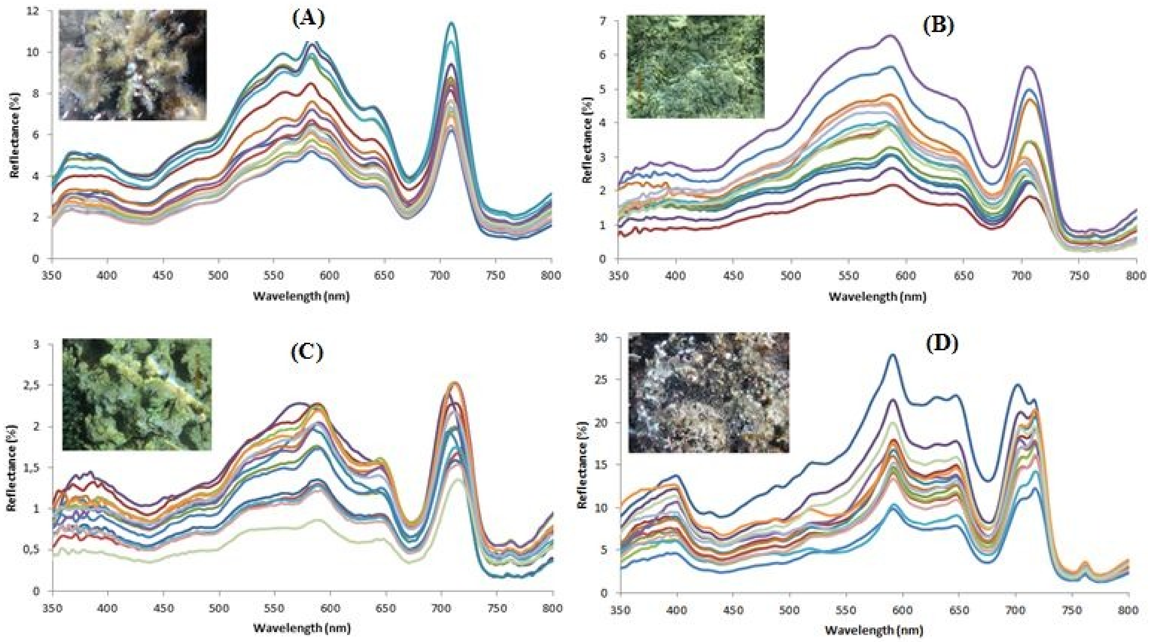


Figure 3. Averaged reflectance spectra of dead coral category. (A) Dead coral covered with brown algae, (B) Dead coral covered with green algae, (C), Dead coral covered with light green algae, and (D) Dead coral covered with violet algae.

Spectral Derivative Analysis

Spectral derivative analysis was used to more closely examine the spectral differences in reflectance at specific wavelengths. Spectral derivative analysis amplified the subtle differences in spectral reflectance that were revealed in the principal components analysis. The first derivatives reveal that the rate-of-change in reflectance within a 4nm wavelength range are distinctly different for live corals and dead corals covered with algae. Similarly, the second derivatives of live corals differ from those of dead corals covered with algae spectra. First and second derivative were calculated for all live corals samples (Figure 4) and for dead corals covered with algae samples (Figure 4).

The derivatives computed above appear noisy, so the derivative spectra may be primarily characteristic of the noise in each spectrum. Therefore, derivatives were also calculated using averaged spectral reflectance. The average reflectance spectra for live corals and dead corals covered with algae are provided in Figure 3. All spectra measured over substrates that were not classified as live corals were included in the calculation for average dead corals covered with algae. The average dead coral covered with algae spectrum is not representative of a pure bleached coral, but includes the contribution of macro algae. The measured substrates classified as dead corals covered with algae had already been colonized to varying degrees by macro algae.

A calculation of the probability of incorrectly identifying a substrate was performed. The first derivatives of all measured reflectance spectra were calculated and the proportion of cases (measurements) with positive versus negative first derivatives computed.

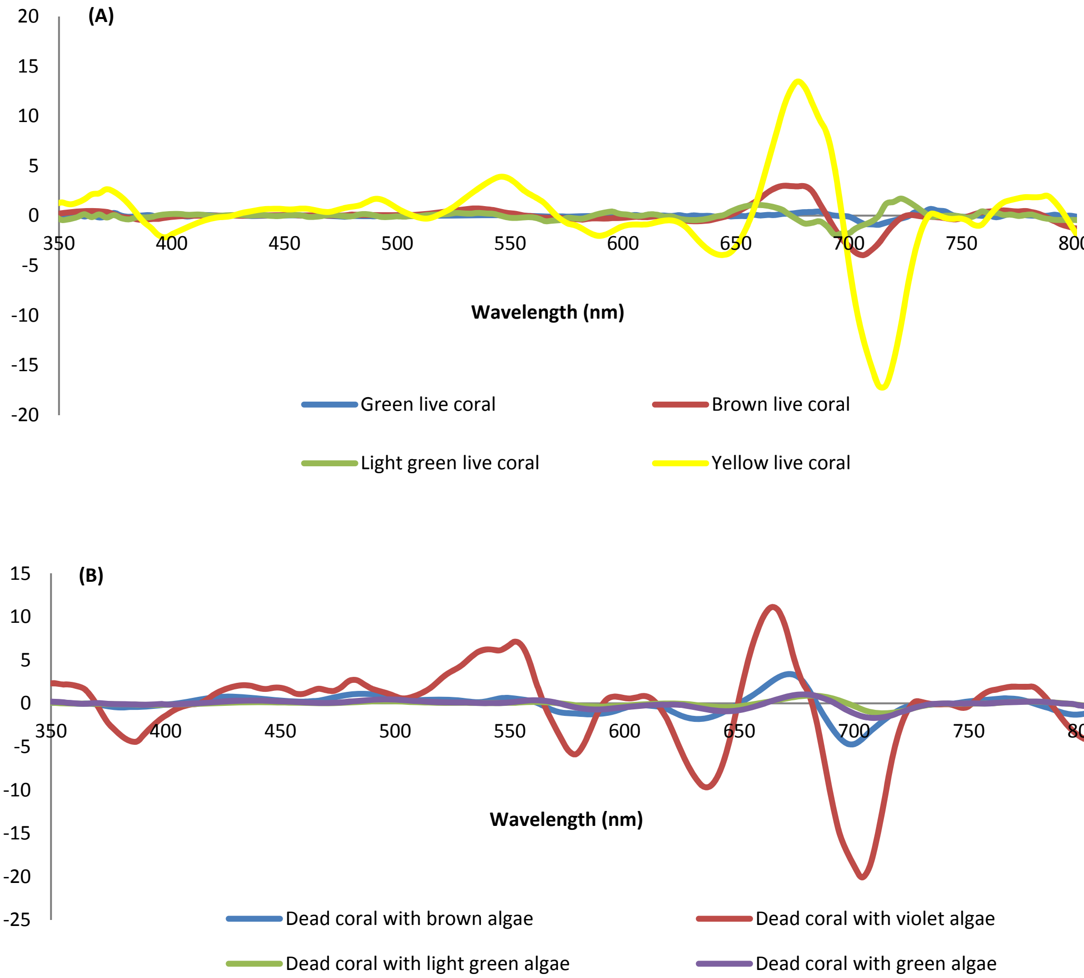


Figure 4. First derivative spectra: (A) Live corals and (B) Dead corals with algae

The first derivative spectra of the live corals is shown in Figure 4A. As it shows, Yellow live coral has the highest (12 at 674 nm) and the lowest reflectance values (-3 at 641 nm) in all live corals categories. Both yellow live coral and brown live coral showed similar peak at 674 nm. While, green live coral peak at 657 nm and green live coral peak at 683. The live corals that has different color showed a narrow variation in the shape of their first derivative spectra. In the second derivative shows that all live corals categories peak around 657 nm – 674 nm and the lowest around 618 nm – 634 nm. However, the second derivative for live corals as it shown at Figure 5A, shows that each corals categories has more spectral shape variation than the first derivative in 4A.

The first derivative spectra of the dead corals covered with algae is shown in Figure 4B. The derivative spectra of the dead coral with algae showed similarities in shape with live coral. The first derivative is not support to discriminate between live corals and dead corals cover with algae spectral. Dead coral with violet algae has the highest and and the lowest reflectance values. The second derivative showed a peak at 647 nm were observed in three dead corals that covered with light green, yellow, and violet algae, while dead coral with brown algae peak at 670 nm. They are showed a high more variation in the shape of their second derivative spectra (Figure 4B and 5B). The first derivative spectra of the live corals and dead corals covered with algae showed similarities in shape, although their overall magnitude was smaller.

The discrimination between healthy and non-healthy corals varies considerably depending on the condition of the non-helathy corals (Dekker et al. 2001). Holden and LeDrew (1998) indicated that best discrimination between healthy and non-helathy coral was possible at 600-660 nm, where the first-derivative values were negative for healthy coral while positive for non-healthy coral. Among the measured spectra, the best discrimination is possible at 640.7 nm and 675.7 nm. These results indicate that there is still spectral confusion within the live corals population, which may be a function of the morphology of the coral it self such that a less dense branching coral will be influenced by the reflectance properties of the bright underlying substrate. The discriminator was apply in this study where second derivative were negative at 667 nm for green live coral and positive for dead coral covered with violet algae. A better discriminator was found at 670 nm for green live coral and positive for dead coral covered with viole algae. At 582 nm is good discrimanator for Dead Coral Algae Violet and live green corals.

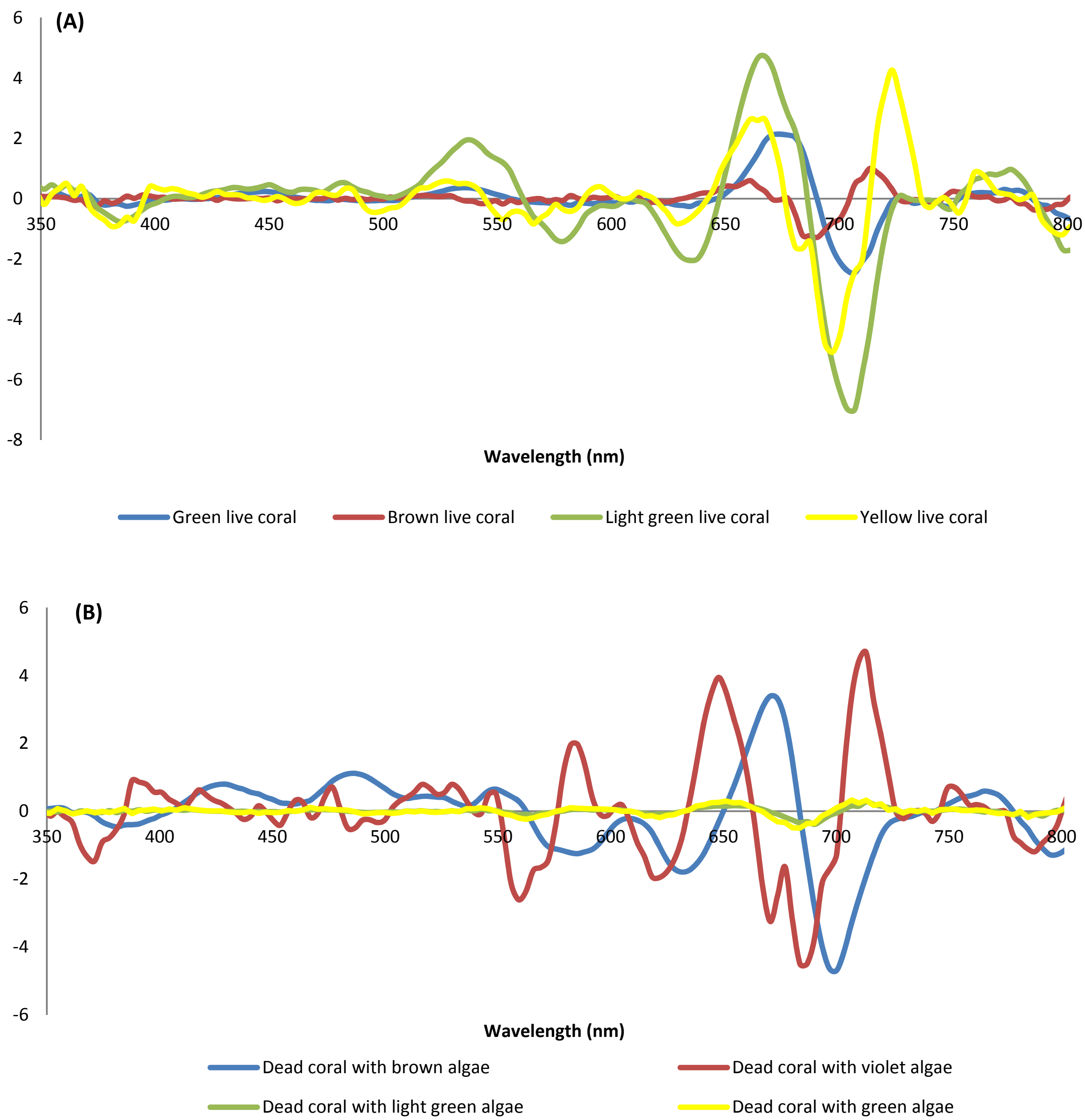
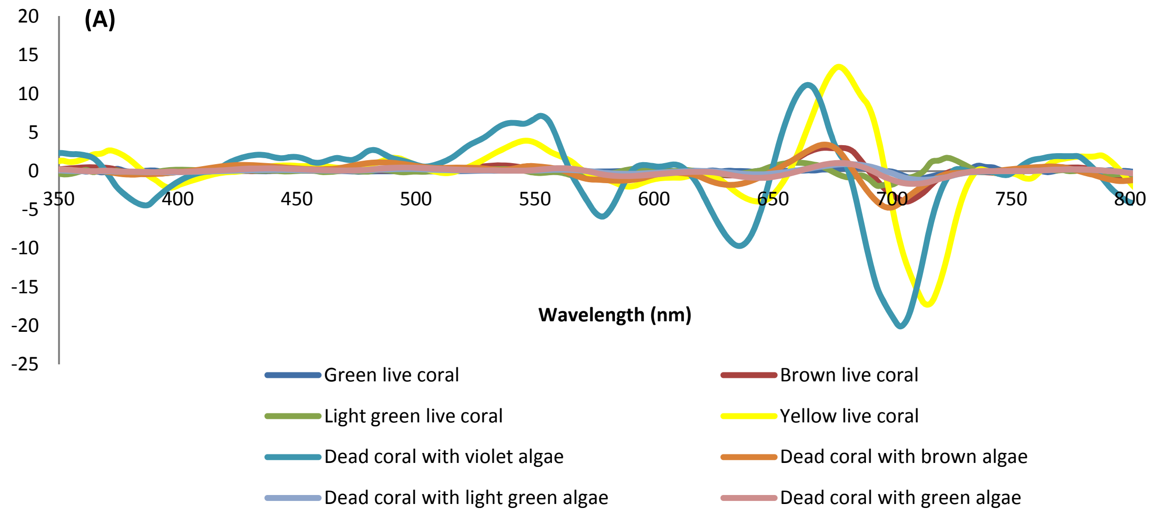


Figure 5. Second derivative spectra: (A) Live corals and (B) Dead corals with algae



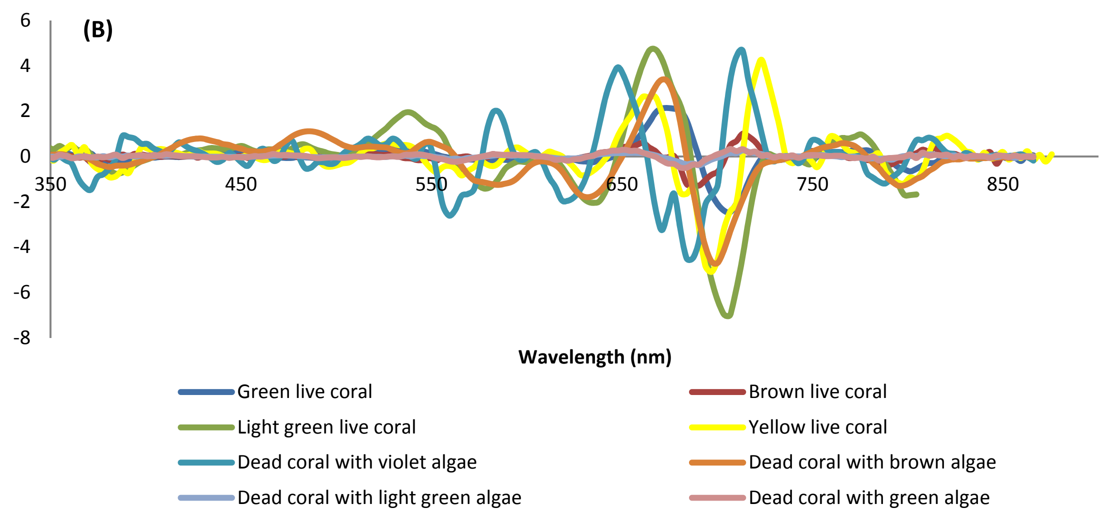


Figure 6. Derivative spectra: (A) First derivative of live corals and dead corals with algae, (B) Second derivative of live corals and dead corals with algae

4. CONCLUSION

In situ spectroradiometric measurement play and important role in the development of remote sensing applications, bridging the gap between laboratory optical measurements and measurements from satelite platforms. The reflectance spectra of a healthy coral are expected to be optically quite different than that of a non-healthy coral based on the difference in color. It would also be expected that a dead coral would have not only a much higher reflectance in general, but also lack some spectral characteristics of shallow water. Derrivative analysis results support the live and dead coral covered with algae have distinct reflectance spectra, but they have hight similarity spectral. Spectral derivative analysis was successful in identifying specific wavelength regions that would be ideal for discrimination. The spectral distinction is present in the visible wavebands that have the ability to penetrate water, so passive optical remote sensors have potential utility in estimating the health of a coral reef ecosystem in terms of the proportion of live and dead coral covered with algae. Spectral derivative analysis appears to be a useful tool for remote identification of subsurface features using high spectral resolution airborne data. This is an important step in establishing consistent and quantitative international databases of accurate and replicable imagery delineating the extent of coral reef ecosystems, and spectral indexes or catalogues indicating the health of ecosystem components. The pigments usually vary in presence and consentration and influence the spectral characteristics of corals. The next, we will studi the variations in pigment composition among live corals and dead corals covered with algae by means of High Performance Liquid Chromatography (HPLC) analysis to further resolve the discrimination of coral.

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