



UNIVERSITI PUTRA MALAYSIA

**BENTHIC HABITAT MAPPING AND CORAL BLEACHING DETECTION
USING QUICKBIRD IMAGERY AND Kd ALGORITHM**

KEIVAN KABIRI

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**BENTHIC HABITAT MAPPING AND CORAL BLEACHING
DETECTION USING QUICKBIRD IMAGERY AND K_d ALGORITHM**

By

KEIVAN KABIRI

**Thesis Submitted to the School of Graduate Studies,
Universiti Putra Malaysia, in Fulfilment of the
Requirements for the Degree of Doctor of Philosophy**

December 2013

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DEDICATION

I would like to dedicate this thesis to my mother and soul of my father.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirement for the degree of Doctor of Philosophy

**BENTHIC HABITAT MAPPING AND CORAL BLEACHING DETECTION
USING QUICKBIRD IMAGERY AND K_d ALGORITHM**

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December 2013

Chair: Biswajeet Pradhan, PhD

Faculty: Engineering

Remotely sensed satellite images have shown their abilities for mapping the benthic habitats in shallow waters. In this regard, estimating depth values is typically a key phase in benthic habitat mapping using multi-spectral satellite imagery. The overall objective of this thesis was applying QuickBird imagery for benthic habitat mapping (with specific attention to the coral reefs) and detecting bleaching in coral reef communities. First objective of this research is to apply a general linear model to compute the parameters with unknown values of the Stumpf's methodology for depth estimation utilizing multi-spectral satellite images. In this regard, two QuickBird satellite images (2005 and 2008) were corrected geometrically and radiometrically prior to accomplishing the main analysis. A total number of 80 and 74 points with known depth values were available for the years 2005 and 2008 images respectively. Half numbers of these points were selected to determine the mentioned parameters using minimizing the sum of the squared residuals, and the other points were used for accuracy assessment of the applied method. On the other hand, diffuse attenuation coefficient (k_d) is another critical parameter for benthic habitat mapping using remotely sensed data. In this regard, the second objective of this research was to develop an approach to estimate k_d in blue and green bands of QuickBird satellite image. To do this, the Lyzenga's method was utilized to determine the ratio of k_d in different bands of satellite image. Afterwards, NASA- k_d^{490} algorithm was modified and then applied to determine k_d^{490} in each pixel of image. After determining the k_d^{490} values as k_d for blue band, the k_d values for green and red bands were subsequently obtained by using results obtained from Lyzenga's method. It is a well-known fact that, Sea Surface Temperature (SST) is an important parameter which can affect the health of coral reef communities. Therefore, as third objective of this research, it is focused on the studies of fluctuations of SST values in near-shore waters around the studied area between 1985 and 2009 using NOAA-Pathfinder-5 dataset and field observations. Subsequently, the results were analyzed to assess the impacts of these fluctuations on main coral reef communities. Finally, as fourth objective of this thesis, the feasibility of using multi-temporal satellite images for detecting bleaching events was investigated. Two aforementioned QuickBird images were selected to detect 2007 bleaching incident in the study area and then, the accuracy of results was

compared with *in situ* observations. In the proposed procedure, pre- and post-bleaching images were classified and changes in reflectance values within coral classes were interpreted as bleaching areas.

Final results of the applied methodology for depth estimation revealed correlation values equal to ~ 0.84 and ~ 0.83 between estimated and measured depth values, while their mean values were $\sim 2.06 \pm 1.44$ m and $\sim 1.75 \pm 1.33$ m for 2005 and 2008, respectively. Additionally, the results obtained for determination of k_d values proved to be consistent in the areas deeper than 2m between estimated values using the proposed approach and the results obtained from Mumby and Edwards' methodology. The results also demonstrated an increment of $\sim 12\%$ in the overall accuracy of classification. Moreover, statistical analyses on SST data showed a meaningful and positive correlation between the SST values and bleaching in coral reefs. Specifically, in August 2007, this phenomenon was clearly observable when most of the corals were affected by the bleaching phenomenon while the SST values were $\sim 1.5^\circ\text{C}$ higher than the normal situation. Finally, by using the applied method for detecting bleached corals, results confirmed that it is possible to eliminate the effect of misclassification between bleached corals and sand as well as algae-covered corals and live corals while the proposed technique could detect $\sim 28\%$ of algae-covered bleached corals.

It is concluded that a positive anomaly more than 1°C in SST values, may lead to bleaching in the coral reef communities. Additionally, to detect this event, it is necessary to having at least two high resolution satellite images for pre- and post-bleaching date. In this regard, applying correction on substrate reflectances needs to have knowledge about depth and k_d values and consequently, may increase the final results of image classifications.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**BENTHIC HABITAT PEMETAAN DAN CORAL PELUNTURAN
PENGESANAN MENGGUNAKAN QUICKBIRD IMEJAN DAN K_d
ALGORITMA**

Oleh

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Jauh rasa imej satelit telah menunjukkan kebolehan mereka kerana memeta habitat bentik di perairan cetek. Dalam hal ini, menganggarkan nilai-nilai kedalaman lazimnya satu fasa utama di pemetaan habitat bentik menggunakan imejan satelit pelbagai spektrum. Objektif keseluruhan tesis ini menggunakan gambaran QuickBird untuk pemetaan habitat bentik (dengan perhatian khusus kepada terumbu karang) dan mengesan melunturkan komuniti terumbu karang. Objektif pertama penyelidikan ini ialah untuk memohon satu model linear umum mengira parameter dengan nilai-nilai tidak dikenali kaedah Stumpf untuk anggaran kedalaman menggunakan imej satelit pelbagai spektrum. Dalam hal ini, dua imej satelit QuickBird (2005 dan 2008) dibetulkan secara geometri dan radiometrically sebelum mencapai analisis utama. Satu jumlah keseluruhan 80 dan 74 mata dengan kedalaman terkenal nilai tersedia ada untuk tahun 2005 dan 2008 imej masing-masing. Nombor-nombor separuh mata ini dipilih untuk menentukan parameter disebut menggunakan mengurangkan jumlah baki selaras, dan mata yang lain digunakan untuk penilaian ketepatan kaedah gunaan. Sebaliknya, menyebarkan pekali pelemahan (k_d) ialah satu lagi parameter kritikal untuk pemetaan habitat bentik menggunakan jauh rasa data. Dalam hal ini, matlamat kedua penyelidikan ini ialah untuk membangunkan satu pendekatan mentaksir k_d di biru dan kumpulan hijau imej satelit QuickBird. Lakukan ini, kaedah Lyzenga digunakan untuk menentukan nisbah k_d di kumpulan lain imej satelit. Kemudian, algoritma NASA- k_d^{490} telah diubah dan kemudian digunakan untuk menentukan k_d^{490} di setiap piksel imej. Setelah menentukan nilai-nilai k_d^{490} sebagai k_d untuk jalur biru, nilai-nilai k_d untuk hijau dan jalur merah kemudiannya diperolehi dengan menggunakan keputusan diperolehi dari kaedah Lyzenga. Ia satu fakta yang sudah diketahui bahawa, Sea Surface Temperature (SST) ialah satu parameter penting yang boleh menjejaskan kesihatan komuniti terumbu karang. Akibatnya, sebagai matlamat ketiga penyelidikan ini, ia ditumpukan di kajian naik turun nilai-nilai SST di perairan hampir pesisir sekitar kawasan dirancang antara 1985 dan 2009 menggunakan NOAA-Pathfinder 5 dataset dan pemerhatian lapangan. Kemudiannya,

keputusan dianalisis untuk menilai impak naik turun ini di terumbu karang utama masyarakat. Akhirnya, sebagai objektif keempat tesis ini, kemungkinan menggunakan imej satelit pelbagai masa kerana mengesan melunturkan acara telah disiasat. Dua imej-imej QuickBird tersebut sebelumnya dipilih untuk mengesan 2007 melunturkan kejadian di kawasan kajian dan kemudian, ketepatan keputusan ialah dibandingkan dengan pemerhatian-pemerhatian in situ. Di prosedur dicadangkan, pra dan imej-imej pasca pelunturan diklasifikasikan dan perubahan di nilai-nilai kepantulan dalam kelas-kelas karang telah diterjemahkan sebagai melunturkan kawasan.

Keputusan muktamad kaedah gunaan untuk anggaran kedalaman mendedahkan nilai-nilai korelasi sama ~ 0.84 dan ~ 0.83 antara kedalaman diukur dan dianggarkan nilai, manakala nilai min mereka $\sim 2.06 \pm 1.44$ m dan $\sim 1.75 \pm 1.33$ m untuk 2005 dan 2008, masing-masing. Tambahan pula, keputusan diperolehi untuk keazaman nilai-nilai kd dibuktikan konsisten di kawasan itu lebih dalam daripada 2m antara nilai yang dianggarkan menggunakan pendekatan yang dicadangkan dan keputusan diperolehi dari kaedah Mumby and Edwards. Keputusan juga menunjukkan satu tambahan $\sim 12\%$ di ketepatan keseluruhan pengelasan. Tambahan pula, analisis statistik di data SST menunjukkan satu korelasi positif dan bermakna antara nilai-nilai SST dan melunturkan terumbu karang. Lebih-lebih lagi, pada Ogos 2007, fenomena ini dengan jelas dapat dilihat apabila kebanyakan daripada batu karang terjejas oleh fenomena pelunturan manakala nilai-nilai SST $\sim 1.5^\circ\text{C}$ lebih tinggi daripada keadaan biasa. Akhirnya, dengan menggunakan kaedah gunaan kerana mengesan melunturkan batu karang, keputusan-keputusan dipastikan bahawa ia adalah mungkin menghapuskan kesan salah pengelasan antara dilunturkan batu karang dan pasir serta batu karang diliputi alga dan secara langsung batu karang manakala teknik dicadangkan boleh mengesan $\sim 28\%$ diliputi alga melunturkan batu karang.

Disimpulkan bahawa satu anomali positif lebih daripada 1°C di nilai-nilai SST, boleh menjurus melunturkan komuniti terumbu karang. Tambahan pula, untuk mengesan acara ini, ia perlu mempunyai sekurang-kurangnya dua satelit resolusi tinggi imej untuk pra dan tarikh pasca pelunturan. Dalam hal ini, menggunakan pembetulan di substrat reflectances perlu untuk mempunyai pengetahuan tentang kedalaman dan nilai-nilai kd dan akibatnya, boleh meningkatkan keputusan muktamad klalsifikasi imej.

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APPROVAL

I certify that a Thesis Examination Committee has met on **16 December 2013** to conduct the final examination of **Keivan Kabiri** on his thesis entitled "**Benthic habitat mapping and coral bleaching detection using QuickBird imagery and k_d algorithm**" in accordance with Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the the Doctor of Philosophy.

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DECLARATION

Declaration by graduate student

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