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Mapping of the corals around Hendorabi Island (Persian Gulf), using WorldView-2 standard imagery coupled with field observations

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ABSTRACT

High spatial resolution WorldView-2 (WV2) satellite imagery coupled with field observations have been utilized for mapping the coral reefs around Hendorabi Island in the northern Persian Gulf. In doing so, three standard multispectral bands (red, green, and blue) were selected to produce a classified map for benthic habitats. The in-situ observations were included photo-transects taken by snorkeling in water surface and manta tow technique. The satellite image has been classified using support vector machine (SVM) classifier by considering the information obtained from field measurements as both training and control points data. The results obtained from manta tow demonstrated that the mean total live hard coral coverage was 29.04% ± 2.44% around the island. Massive corals poritiids (20.70%) and branching corals acroporiids (20.33%) showed higher live coral coverage compared to other corals. Moreover, the map produced from satellite image illustrated the distribution of habitats with 78.1% of overall accuracy.

1. Introduction

It is estimated that the total area of the coral reef communities around the world is less than 0.25% of the entire marine environment but they are home to ~ 25% of all marine lives. This means that corals play a significant role in marine ecosystem, so that continuous mapping of corals is vital for better management of benthic habitats. In this regard, various methods have been employed for mapping the benthic habitats with particular attention to the coral reefs. For instance, implementing field observations in shallow (Greene and Alevizon, 1989; Lirman et al., 2007; Rezai et al., 2010; Kabiri et al., 2012) and deep waters (Freiwald et al., 1999; Huvenne et al., 2002; Singh et al., 2004), utilizing remotely sensed data (Mumby et al., 1997, 2004; Purkis and Pasterkamp, 2004; Andréfouët, 2008; Kabiri et al., 2013a, 2013b; Manessa et al., 2014; Kabiri, 2017), applying side scan sonars and acoustic backscatters (Allen et al., 2005; Riegl and Purkis, 2005; Prada et al., 2008; Foster et al., 2009), as well as operating aerial photography using different platforms (Sheppard et al., 1995; Cuevas-Jiménez et al., 2002; Lewis, 2002; Palandro et al., 2003; Kabiri et al., 2014) are some of the methods employed for coral reefs mapping. In addition and as a combined methodology, Walker et al. (2008) proposed a GIS-based method for mapping the coral reefs, based on aggregation of different methods including acoustic ground discrimination, laser bathymetry, sub-bottom profiling, and aerial photography data. However, all of the aforesaid techniques have their own advantages and disadvantages which may made them appropriate or inappropriate to use in a specific case of study. For example, field observations are usually most accurate technique for benthic habitat mapping in nearby coastal areas, but it is the most costly method as well, and cannot be applied in inaccessible areas. In contrast, remotely sensed data is applicable for remote areas with lower cost; but the resulted maps will be less accurate compared with field measurements.

Satellite remotely sensed data have shown their capacities for mapping the benthic habitats from early 1980's when Lyzenga (1978, 1981) modeled the basic physical concepts of water column effects on substrate reflectance values. Afterwards, Bierwirth et al. (1993) employed a mathematical constraint to enhance obscured substrates beneath the shallow water bodies and then based on their findings, Purkis and Pasterkamp (2004) proposed a model to determine bottom reflectance values from remotely sensed data. However, the main contribution of satellite images for coral reefs mapping was started in early 2000 after launching platforms carrying high spatial resolution sensors such as IKONOS with 3.2 m resolution (at nadir) in multispectral bands (Andréfouët et al., 2003; Mishra et al., 2005), QuickBird with 2.44 m resolution in multispectral bands (Mishra et al., 2006; Kabiri et al., 2012), and GeoEye-1 (Iovan et al., 2015; Grizzle et al., 2016) and WorldView-2 (Collin and Hench, 2012; Collin and Planes, 2012; Warren et al., 2016) with 1.84 m resolution in multispectral bands. Recently

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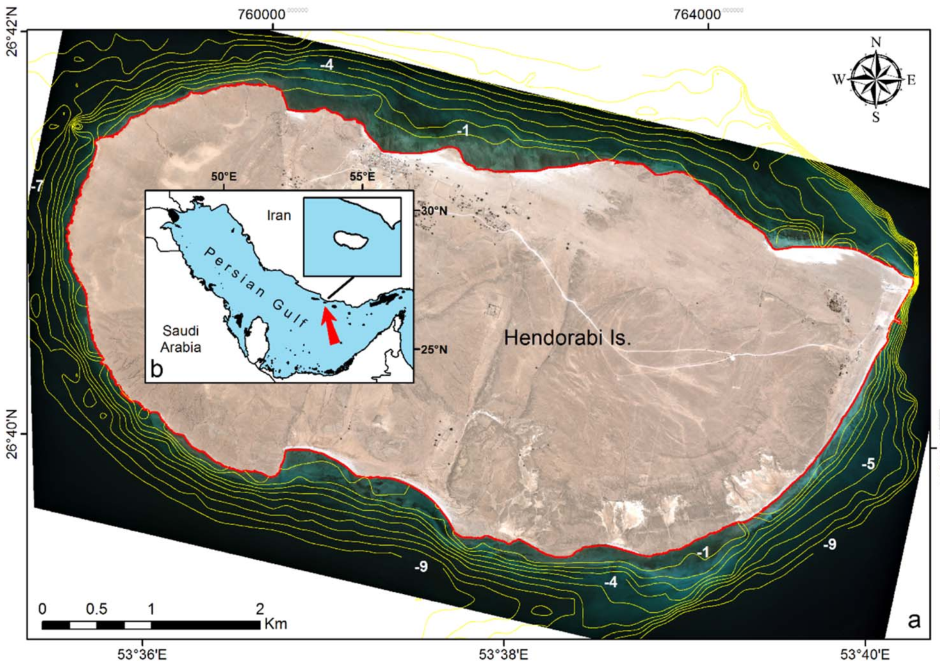

Fig. 1. WorldView-2 (WV2) satellite image captured on July 21, 2012 from the study area (a). Location of Hendorabi Island in the northern Persian Gulf (b).

launched WorldView-3 platform (in August 2014) has extremely high spatial resolution ~1.2 m at nadir which may be called as the best sensor for precise coral reef mapping so far.

The main objective of this study is to assess the benefits of using high resolution WorldView-2 (WV2) satellite imagery for mapping the coral reefs and their percentage coverage around Hendorabi Island located in the northern Persian Gulf. In doing so, a cloud free standard WV2 image (taken on July 21, 2012) from the study area was selected. In addition, a field survey was implemented around the Island including manta tow technique together with photo-transecting from the surface of water by snorkeling. Then, by applying some of the data obtained from field observation as training data, the satellite image was classified based on support vector machine (SVM) classifier. Afterwards, other independent field observations were utilized as control point to assess the accuracy of classified map.

2. Study area

Hendorabi (known as Hendourabi and Hendurabi as well) Island is located in the north of the Persian Gulf, between coordinates 26° 29.25′–26° 41.75′ N and 53° 35.5′–53° 40.3′ E (Fig. 1). The minimum distance between Island and southern Iran mainland is ~6 km. The area of this elliptical shape Island is ~22 km^2 while its perimeter is ~24 km. The air temperature of this Island fluctuates between 14 °C (minimum value in wintertime) and 41 °C (maximum value in summertime), and water temperature varies between 23 °C and 34 °C (Moradi and Kabiri, 2015). Our field observations showed that the average depth of the areas covered by coral communities is 4 m, and the main corals are happened on depths between 1 and 6 m. Additionally, regarding to the data obtained from Iranian Hydrography Organization (http://iranhydrography.ncc.org.ir/), the maximum tidal range of the study area is ~1.8 m. Different types of hard corals such as *Porites, Favia, Acropora* spp., *Pavona* and *Platygyra* sp. exist in this area. The historical data about situation of corals in this area is rare but our recent field observations showed that are similar to other coral reef communities in the Persian Gulf (Kabiri and Moradi, 2014; Sheppard, 2016) most of the coral species in Hendorabi Island have experienced mass mortality and bleaching in different levels in August 2015 and 2017, due to the extremely high water temperature.

3. Materials and methods

3.1. Field measurements

Two types of field observations were implemented in the study area including manta tow and photo-transecting by snorkeling. The main purpose of manta tow observations was to provide an overall distribution of hard corals around the island. In contrast, the aim of photo-transecting was to produce precise geo-referenced photo-transects to have reliable data for further analysis in satellite image processing. During the manta tow surveying, the diver was towed by boat while he was snorkeling in the water surface. Then he signaled the other operator on the boat to stop the vessel, once he reached to the areas covered by corals. At this time, the estimated percentages of each life form (including the hard corals) were recorded together with the coordinates of location (measured by a hand-held Garmin™ 78s GPS). This was done all around the Island on the 25th August 2015, a total number of 84 points (Fig. 2).

The other method of filed observation which performed in this study was photo-transecting. It has been performed in two dates including 25th August 2015 and 29th August 2017, when in both dates the coral bleaching event in the Hendorabi Island was observed and reported by local divers. In this regard, at the first step the clock of photo-camera was exactly synchronized with GPS clock. This enabled us to extract the coordinates of each photo in post-processing step. Afterwards, the GPS was covered by a waterproof package and then was attached to the diver (Fig. 3, a). Additionally, a small buoy was attached to GPS for keeping it floated during the snorkeling of diver (Fig. 3, b). Then, the diver swam within the main coral sites around the Island and took several overlapped photos from the water surface (Fig. 3, c), while the track option of GPS was on (with 1 s time interval between the records). The location of these transects were selected based on the results of manta tow survey, where the coral patches comprising different types of corals were located. In the following, Autodesk® Raster Design software was used to make a mosaic from the taken photos. In doing so, the coordinates of each photo were extracted from the GPS tracking data with regard to the time they were taken. Then, the photos were inserted in the software one by one and were allocated on their own right position by moving, rotating, and rescaling according to their