

# Coral reefs mapping using parasailing aerial photography-feasibility study: Kish Island, Persian Gulf

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**Abstract** A novel technique of aerial photography was examined using parasailing for mapping the coral reefs located in the coastal waters of Kish Island (central north of the Persian Gulf). A total number of 11 overall and 96 overlapped aerial photos were taken (6 overall and 67 overlapped were selected to use) and then were mosaicked and geo-corrected using ENVI® 5.1 image processing software by considering 8 pre-located diving buoys as ground control points. Afterwards, the corrected overall photos were stitched and used to produce a schematic map while the mosaic was digitized by applying a manual on-screen digitizing method in AutoCAD® raster design software, and a GIS-based topological thematic map was generated as output. The final results revealed that the method is applicable to map the coral reefs, while the ability to distinguish coral types by visual interpretation is the most advantageous factor for the proposed technique. Particularly in the studied area, an area ~4,500 m<sup>2</sup> comprising *Porites* and *Acropora* spp. as dominant coral genus could be mapped. Additionally, the low cost, quick and easy to manage and implementation, as well as producing precise thematic maps are considered as advantages of applying the proposed technique, in comparison with other alternative methods such as satellite imagery and field observations. In contrast, the limitation of this method is to use it in remote regions or areas with high turbid waters where it is not possible to interpret the coral types visually on the photos.

**Keywords** Coastal mapping · Close-range photography · Remote sensing · Benthic habitats · Coral reefs

## Introduction

Regular mapping of the coral reefs in the near-shore areas is a necessity for benthic habitats conservations. So far, several methodologies have been implemented to map the benthic habitats and particularly coral reefs, such as direct field observations in shallow (Greene and Alevizon 1989; Kabiri et al. 2012; Lirman et al. 2007; Rezai et al. 2010) and deep waters (Freiwald et al. 1999; Huvenne et al. 2002; Singh et al. 2004), satellite remote sensing (Andréfouët 2008; Kabiri et al. 2013a; Mumby et al. 1997; Purkis and Pasterkamp 2004), side scan sonars (Allen et al. 2005; Prada et al. 2008; Riegl and Purkis 2005), acoustic backscatters (Foster et al. 2009) as well as aerial photography (Cuevas-Jiménez et al. 2002; Lewis 2002; Palandro et al. 2003; Sheppard et al. 1995). Walker et al. (2008) showed the ability of a GIS-based combined method including laser bathymetry, acoustic ground discrimination, sub-bottom profiling, and aerial photography data for mapping the coral reefs. Each of the abovementioned methods has its own pros and cons which are important for managers and decision makers to choose a particular method in each study. For example, while direct field observations are appropriate and most accurate for nearby coastal areas, it is the most costly method. In contrast, satellite imagery can be applied for remote areas with lower cost; but the results will be less accurate.

The close range aerial photography is another alternative methodology for benthic habitats mapping. In doing so, a camera with an accurate and high resolution multispectral/hyperspectral sensor can be embedded in an aerial vehicle (such as airplane or hexacopter), a balloon, a wing aircraft, a drone or even a kite to provide photos from the coral reefs (Rützler 1978; Scoffin 1982; Austin 2010; Añonuevo 2013; Fleur 2013).

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Thereafter, in post processing step, it will be possible to map the corals by using image processing analysis as well as visual interpretations (depending on the sensor used).

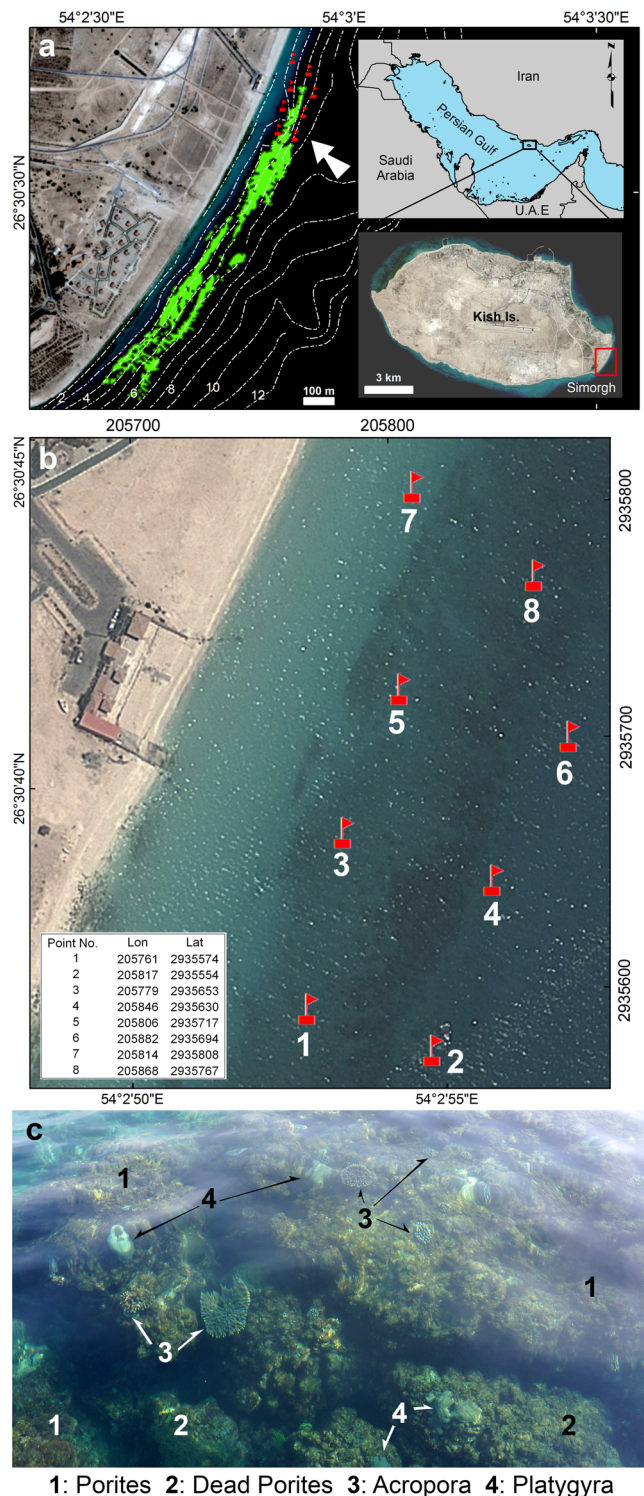
In this research, it is aimed to examine an alternative approach to map the coral reefs using aerial photography. In this regard, the main objectives are i) to examine the capability of a novel technique for coral reefs mapping using parasailing photography, and ii) to assess the capability of captured photos to differentiate the coral types by visual interpretations. Kish Island, in the Persian Gulf, was chosen as the suitable study area, because this method is easily applicable in this area with low coral diversity, where the coral reefs are under different threatening factors such as bleaching, tropical storms, anthropogenic impacts caused by high tourism activities, etc. The results obtained from this technique will be compared with some of the other existing methods and advantages and/or disadvantages of each will be discussed.

### Study area

Kish Island is located in the northern part of the Persian Gulf and lies between  $26^{\circ} 29' - 26^{\circ} 34' N$  and  $53^{\circ} 53' - 54^{\circ} 03' E$  (Fig. 1a). It is one of the most touristic Islands in Iran having high human activities impacting the marine environment. According to the Iranian meteorological organization (<http://irimo.ir>), the air temperature of this Island fluctuates between  $15^{\circ} C$  (minimum value in wintertime) and  $40^{\circ} C$  (maximum value in summertime), and water temperature varies between  $22^{\circ} C$  and  $33^{\circ} C$ . The average depth of the area is 5 m, and the main corals are located on depths between 3 and 7 m (Kabiri et al. 2012). Moreover, based on data obtained from Iranian hydrography organization (<http://iranhydrography.ncc.org.ir/>) the maximum tidal range of the study area is  $\sim 1.8$  m. In the present study, a small area in northern part of the Simorgh site was selected to examine the feasibility of proposed technique (Fig. 1b). Simorgh is the main coral reef site located in the southeast of the Island and different types of corals such as *Porites*, *Acropora* spp., and *Platygyra* sp. exist in this area (Fig. 1c). Previous studies have assessed the coral reefs of this area including direct field observations (Kabiri et al. 2012), and remote sensing analysis (Kabiri et al. 2013a, b). The corals have been experiencing some bleaching events such as during 1996, 1998, 2002, and 2007 (Riegl 1999; Rezai et al. 2004; Kabiri et al. 2013a).

### Materials and methods

A total number of 11 overall and 96 overlapped aerial photos were taken of the study area using parasailing photography. However, some of the taken photos were filtered out due to the bad focusing (blurred photos), very high/low flying height



**Fig. 1** a Northern part of the Simorgh site in Kish Island selected as study area to test the method. b Location and Coordinates (in UTM Zone-40) of 8 diving buoys as Ground Control Points. c A photo from different types of existing coral reefs in the study area

(particularly for overlapped photos), duplication, as well as high sun glint effect. The final numbers of appropriate photos were 6 for overall and 67 for overlapped ones. A simple

SONY® NEX-7 full HD photo camera was used for photography where good handling, low weight, extra wide lens (18 mm), high speed of shutter, as well as high resolution imagery (24 megapixels) were the main reasons to select this camera. Before photography, it is necessary to have some ground control points (GCPs) for further analysis to geo-reference the photos. In this regard, 8 buoys were established within the study area and their coordinates were recorded with a handheld GPS. Afterwards, the taken photos were mosaicked, geo-registered, and digitized to produce coral maps from the studied area. The flowchart of the methodology in this study is shown in Fig. 2.

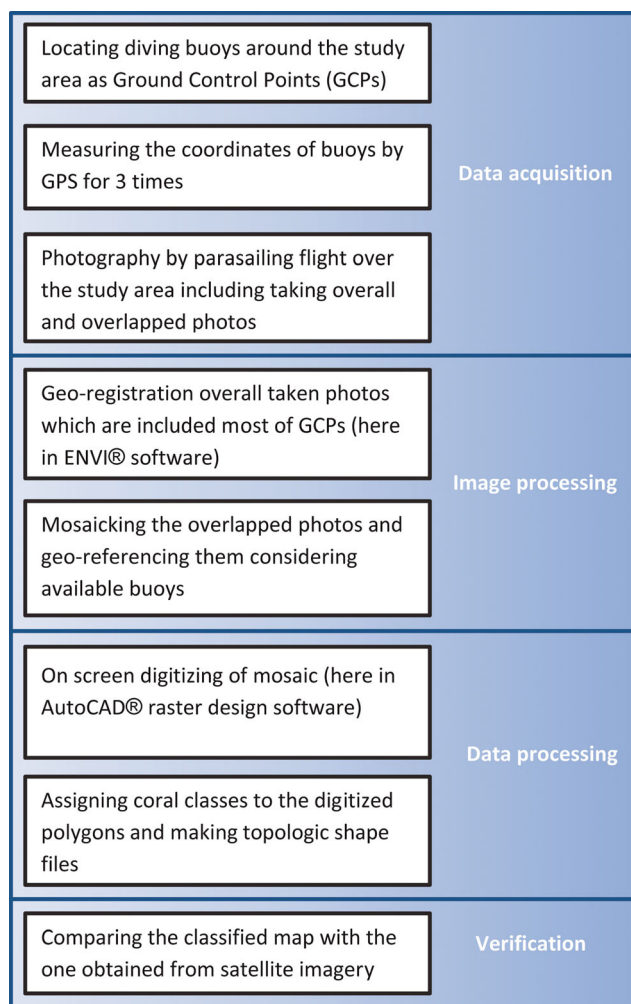
#### Diving buoys as ground control points (GCPs)

To perform geometric corrections and geo-registration of photos in post processing step, it is required to have some GCPs with known coordinates. Typically, in aerial photography from urban or agricultural areas, these points can be selected from the distinguishable points such as corner of buildings, road junctions, and so on. In contrast, in marine areas such points are usually unavailable; hence, some artificial objects are required. For doing so, 6 diving buoys were established with two other pre-fixed buoys. It means there are 8 GCPs available for further analysis (Fig. 1b). To locate the diving buoys and to avoid repositioning or sinking of the buoys, it is essential to consider tidal water level fluctuations. In the pre-processing step, the tide data of the Kish Island were extracted from Iranian hydrography center website which shows the water level will rising up ~20 cm between 9:00 am and 10:00 am on 27 April 2014 (the scheduled time for performing the flight).

A Speedtech® depth-mate portable sounder (Fig. 3a) was used to measure the water depth at each point. Then the buoys were connected to a sinker (Fig. 3b) by a rope (with the length equal to measured water depth plus predicted water level changes due to tide) and fixed in the desired place (Fig. 3c and d). To avoid drifting or sinking of the buoys at the time of each observation, a diver tried to adjust the length of rope to keep it perpendicularly (Fig. 3e). Thereafter, the coordinates of all buoys were recorded by a handheld GPS (Garmin™ GPS 78sc) for 3 times using differential GPS mode (DGPS). This mode can increase the typical 10 m accuracy of GPS to 3–5 m (Garmin owner's manual, [http://static.garmincdn.com/pumac/GPSMAP\\_78\\_OM\\_EN.pdf](http://static.garmincdn.com/pumac/GPSMAP_78_OM_EN.pdf)). Finally, the mean values were considered as the final coordinate values (Figs. 1b and 3f).

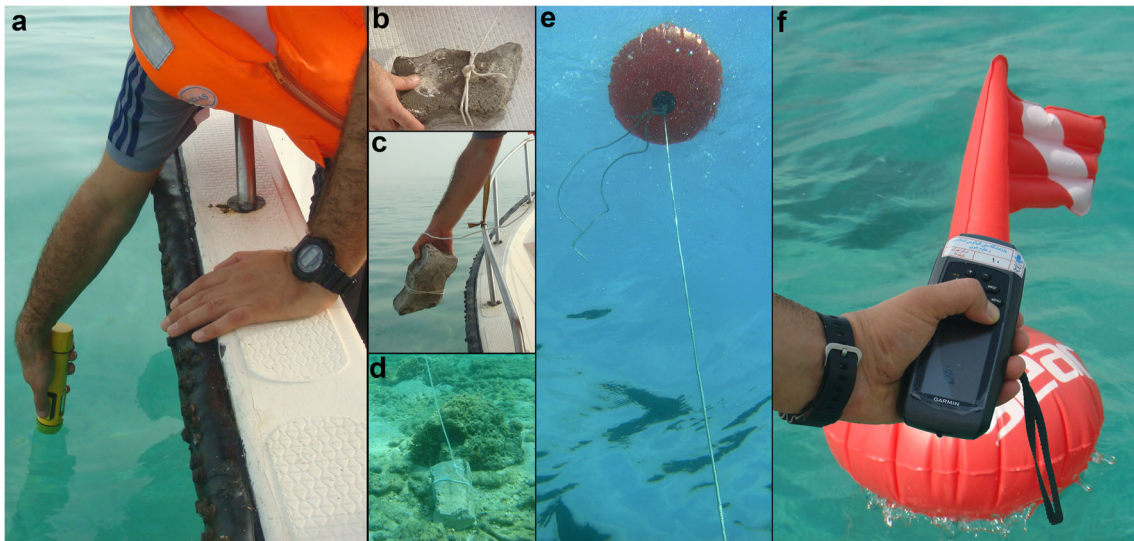
#### Performing parasail flight over the study area

After placing the buoys within the study area, it is possible to perform parasail flight over the area to take the overall and overlapped photos. Figure 4 illustrates scheme of the applied method for taking overlapped photos by parasailing. It should be noted that the ideal results will be achieved if the



**Fig. 2** Flowchart of concise methodology employed in the present study

photography implemented during the low tide time, with calm waters. Moreover, the time of flight should be chosen so that unpleasant sun glint effects (which happened usually during noon) are less. For this study, parasailing was specifically performed between 9:14 am and 9:43 am, when the water level was rising up after low tide happened in 8:00 am, and where the sun glint was low on the surface of the water. Wind speed and direction are other important parameters which should be considered to manage and design the operation. For example the wind speed more than 10 kts can make the flight instable and accordingly may decrease the quality of taken photos. During the period of our flight, the wind speed was less than 6 kts. To avoid unfavorable effect of the boat wake on the taken photos, the best results will be achieved when the boat direction is perpendicular to the wind direction (Fig. 4). It is ideal, if the height of parachute is constant during the time of photography, this situation will happen rarely due to the variations in wind and boat speed and/or direction. Particularly for this research, the mean flying height was ~25 m where this value was fluctuated between 20 and 30 m



**Fig. 3** **a** Measuring the depth by Speedtech® depth-mate portable sounder. **b–d** Connecting the buoys to the sinker and fixing it in the desired place. **e** Adjusting the length of rope to keep the buoy perpendicular. **f** Recording the coordinates of the buoy by GPS

in most time of photography. This variation in flying height should be considered in post processing step by resizing the photos before mosaicking them. To avoid high inconsistency among the photo sizes, those photos taken from the elevation higher than 35 m and lower than 15 m were filtered out. Finally, in post-processing step, photos should be rotated and resized before being mosaicked.

By considering all abovementioned parameters and limitations, parasailing was performed while the boat sailed parallel to the coastline, so that the corals could be located between boat track and shoreline (Fig. 4), and photos were taken manually (Fig. 5). The flight was repeated for 3 times for taking more overlapped photos to obtain more accurate and detailed results.

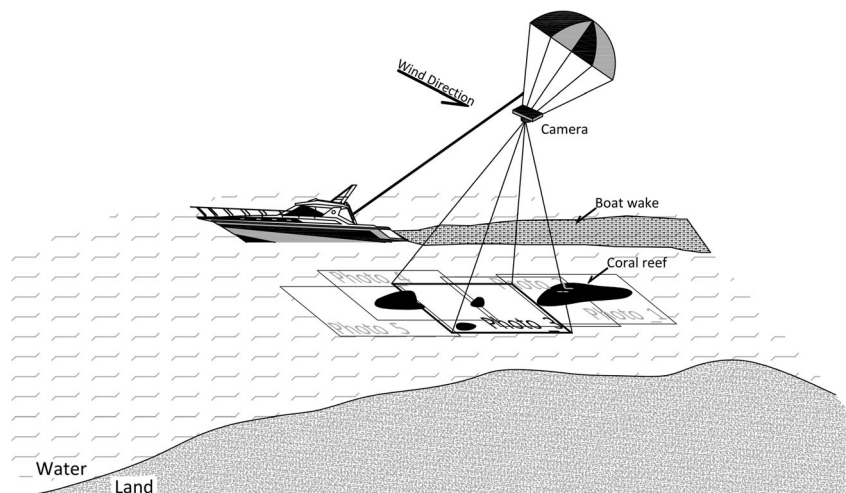
Two types of photos were taken in this study including remote overall (6 photos) and close overlapped (67 photos after eliminating inappropriate ones) photos (Fig. 6). The first type of photos is suitable for producing an overall (but not in detail) map of the corals, where almost all GCPs were

happened in a single scene which enabled the geo-registering of the scene. Moreover, the second type of photos is necessary to increase the accuracy of overall photo to generate more detailed maps from the coral reefs.

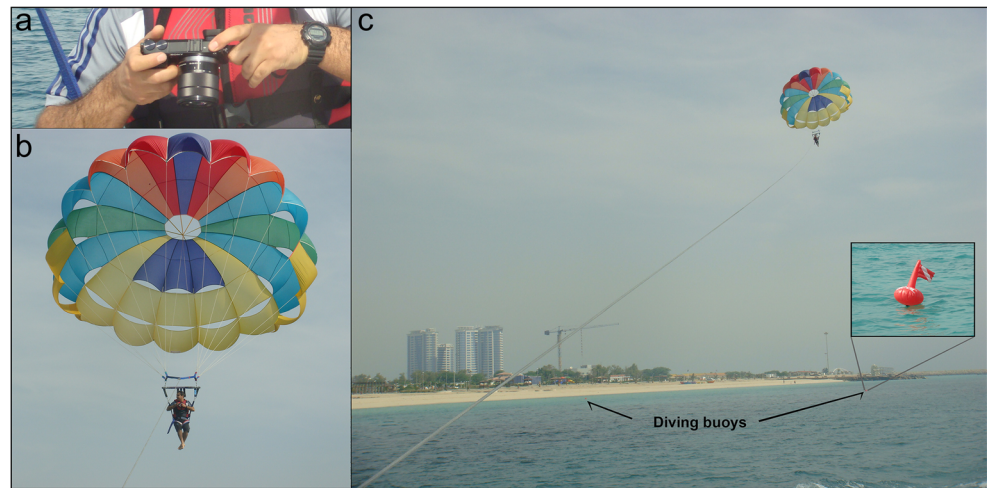
#### Mosaicking and geo-registration of the photos

It is necessary to have an integrated photo from the study area to produce a map of the coral reefs. At the first step, the remote overall taken photos (Fig. 7a and b) were corrected to produce an ortho-rectified image from the studied area. In doing so, the photos were rectified and geo-referenced using ENVI® 5.1 software by considering the aforementioned GCPs (Fig. 7c and d) and triangulation methodology with nearest neighborhood resampling type. Afterwards, the areas comprising coral reefs were masked from the all corrected photos by visual interpretations and then the resulted photos were stitched together (Fig. 7e). To obtain the more accurate results, best

**Fig. 4** The scheme of parasailing flight. To avoid from unfavorable effects of boat wake on photos, the flight should be planned somehow the boat direction to be perpendicular to wind direction. Additionally, the parasail track and subsequently the final overlapped photos should cover the desired habitats (coral reefs) during the flight



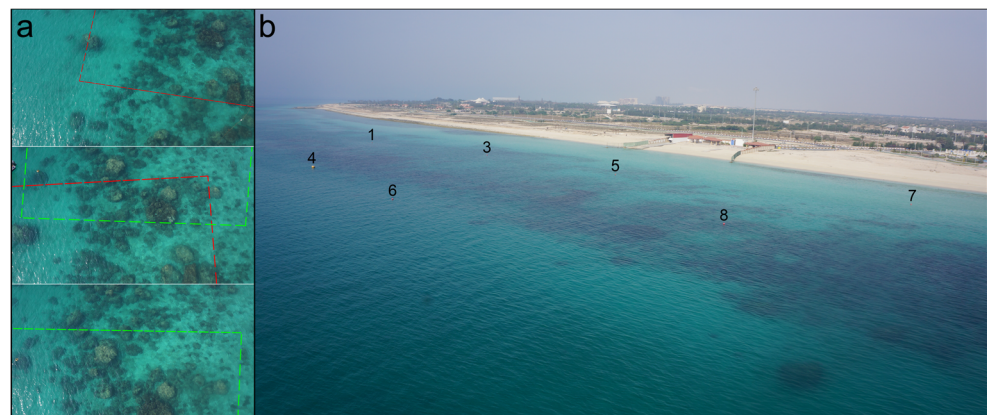
**Fig. 5** **a** SONY® NEX-7 full HD photo camera. **b** Photographer is parachuting and taking the photos. **c** Parasailing over the study area and pre-located diving buoys (GCPs)



part of each photo was selected and the rest was replaced from the other photos with better quality. Consequently, the output of this step was an integrated rectified and geo-registered photo. Nevertheless, the quality of this photo was not good enough for producing a precise map. This means it is necessary to utilize the detailed overlapped photos for increasing the quality of the final map.

As was mentioned before, the overlapped photos must be rotated and re-scaled before they can be mosaicked. To do this, the AutoCAD® raster design software was used to process the photos for mosaicking (Fig. 8a), digitizing (Fig. 8b), and creating the topology. The overlapped photos are ideal when they're taken from significant habitats during each ran of photography; somehow the flight height is constant and the Nadir point and center of photo are close together. Practically, this ideal situation happens rarely, hence the photos need to be edited by moving, resizing and rotating before being mosaicked. For example in the mosaic produced in this study, the noticeable difference in size of photos is due to the variations of flight height (Fig. 8a). Subsequently, to generate an integrated map, the mosaicked photo was geo-registered by moving, rotating, and resizing in AutoCAD® Raster design software and based on observable buoys on it (Fig. 8b).

**Fig. 6** **a** Samples of overlapped taken photos from the coral reefs. The overlap areas are marked by *dashed lines*, **b** A sample of overall taken photo. The numbers of visible GCPs (Buoys) are showed

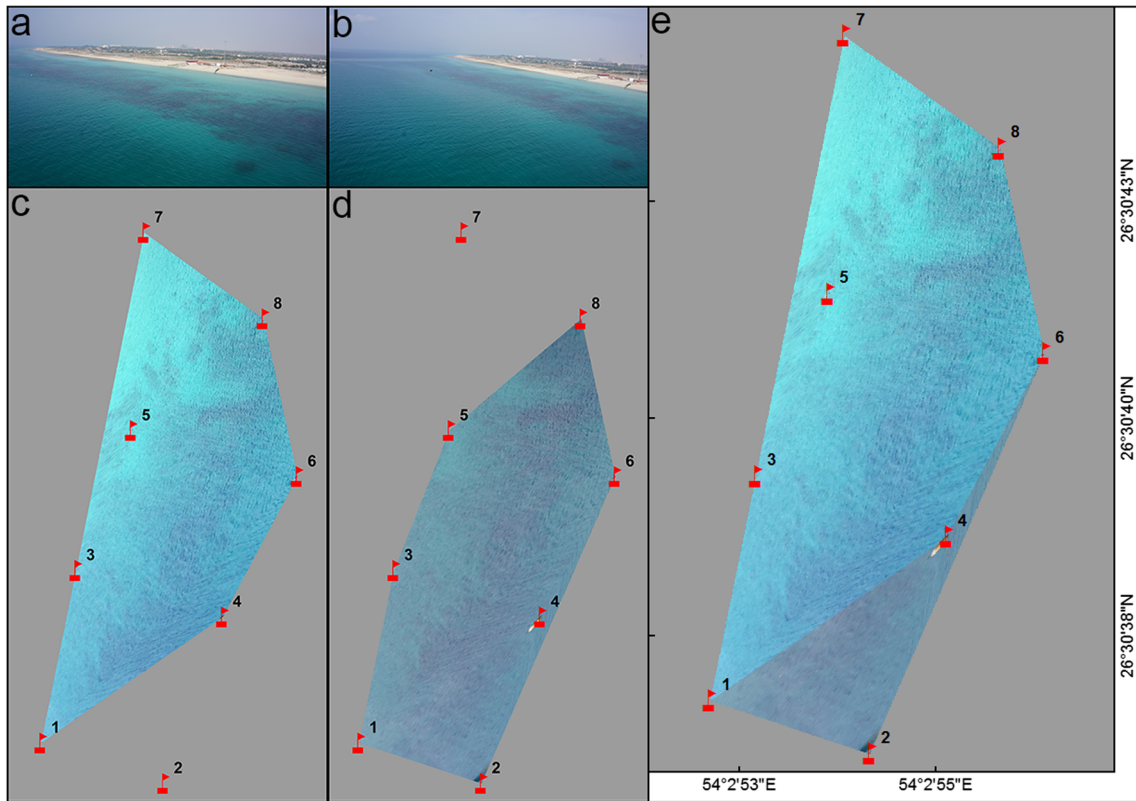


### Digitizing mosaicked photos

The next step in producing a thematic map from the coral reefs is to digitize mosaicked and geo-registered photos. In this regard, an on-screen manual digitizing method was selected by utilizing AutoCAD® Raster design software (Fig. 8b). This is GIS-based software and before making topology, it is possible to clean-up the digitized vectors and eliminate errors such as over-shoots, under-shoots, clusters, etc. Afterwards, it is possible to make topology from the clean-upped digitized polygons, while each polygon is assigned to a class based on coral types identified by visual interpretation of photos. The map prepared in UTM Zone-40 metric coordinate system which means it is possible to determine the area of coral patches.

### Results and discussions

Final results demonstrated that the overall taken photos were just suitable for producing schematic maps and locating the area covered by corals but they were not adequate to differentiate the coral types. Although, rectification of these photos could not be quite accurate where the RMS value was

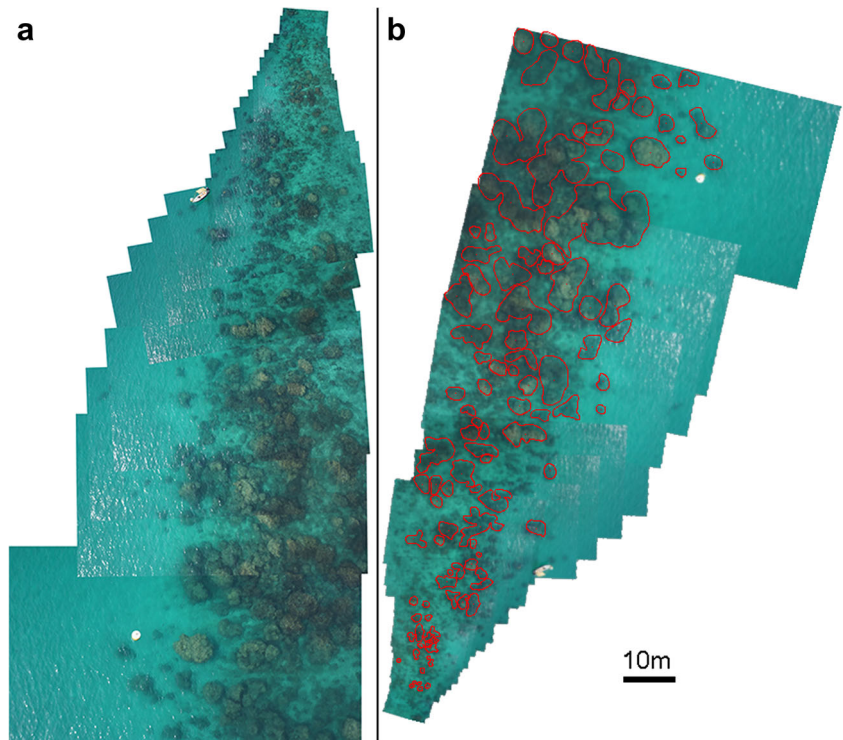


**Fig. 7** a–b Oblique overall photos from the study area. c–d Orthogonal rectified photos using GCPs. e Final geo-registered and integrated photo

~30 pixels (equal to 3 m for the 0.1 m pixel size), this can be acceptable where the positioning accuracy of GCPs by DGPS technique cannot exceed 3 m. In contrast, the overlapped

taken photos could be applied to differentiate the types of coral reefs by visual interpretation. This means that the spatial resolution of these photos is high enough to enable the visual

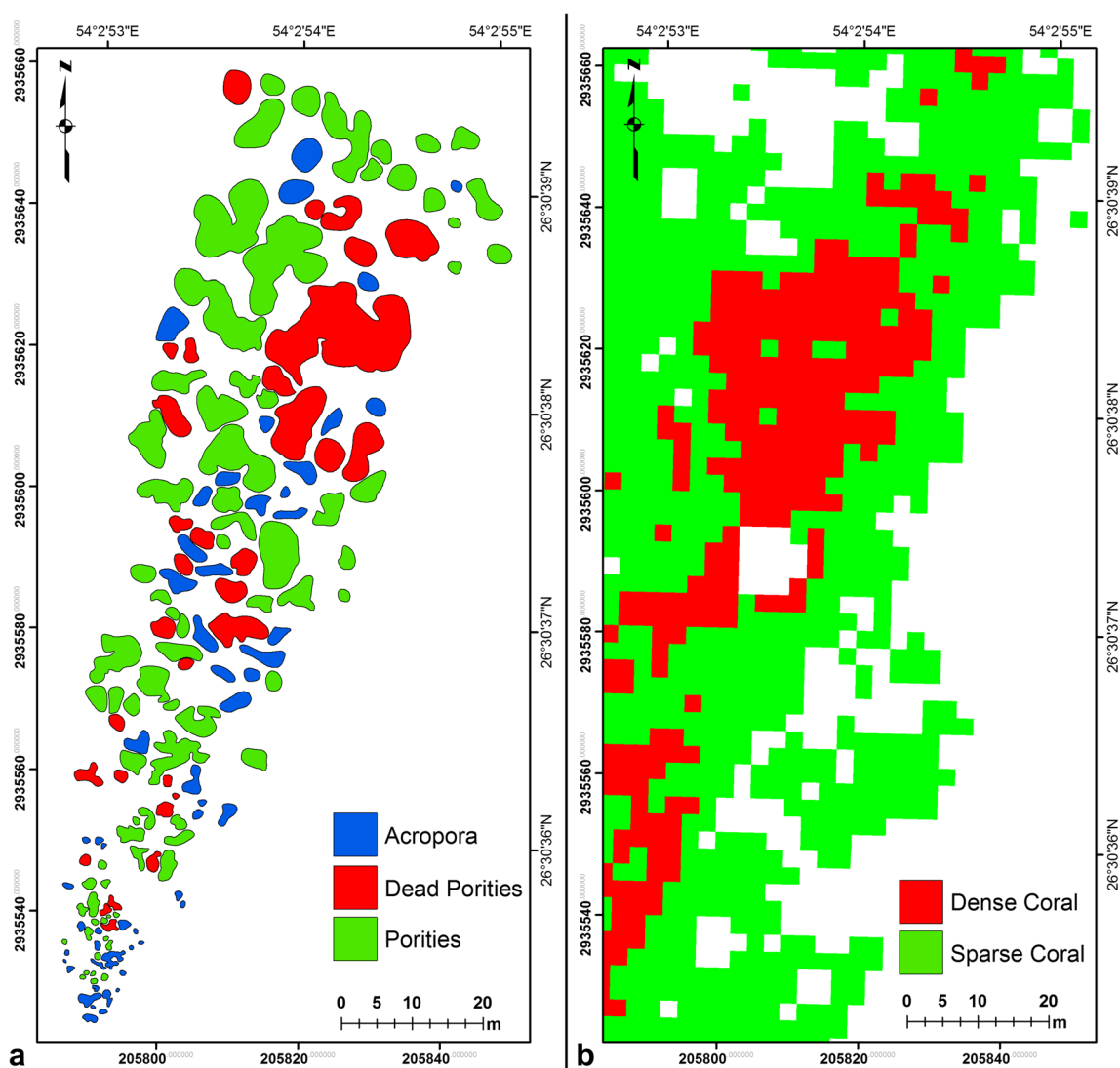
**Fig. 8** a Mosaicked photo. b Digitizing and making topology of corrected (moved, rotated, and rescaled) mosaicked photo



interpreter expert (usually a marine biologist) to distinguish the types of coral reefs. The final integrated topologic and thematic map of the corals produced by proposed methodology is shown in Fig. 9a. The results also showed that the dominant genus of corals which are detectable by utilizing this methodology in this part of Kish Island are *Porites* and *Acropora* spp. and covered  $\sim 4,500$  m<sup>2</sup> of the inspected area. However, when compared with previous studies (Kabiri et al. 2013a, b) the remotely sensed data were only capable to classify the corals as dense or sparse but not distinguish their types (Fig. 9b).

In comparison with other alternative methodologies, the proposed method has some advantages and disadvantages. For example, high spatial multispectral WorldView-2 imagery shows its capabilities for bottom-type identification (Manessa et al. 2014), but it is not a common and reliable methodology for classifying the coral types, particularly in areas with sparse

and small coral patches. Likewise, the maximum overall accuracy of classified maps obtained from Multispectral/Hyperspectral satellite imagery, cannot exceed more than 90 % (Holden and LeDrew 2002; Mishra et al. 2006; Kabiri et al. 2013a, b); whereas based on the present results by employing proposed technique, it is possible to produce accurate thematic maps. Although there was no particular bleached coral in the study area at the time of photography, it is assumed that the method can differentiate the bleached and non-bleached corals, even in the areas with sparse and small patches. It is advantageous to use this method rather than satellite imagery, because it is not possible to detect bleaching phenomenon in coral patches with lesser than 23 % of bleaching in each pixel (Yamano and Tamura 2004). Moreover, multi-temporal/multi-spectral high resolution satellite imagery can increase the accuracy of detecting bleached corals, but the overall accuracy cannot exceed more



**Fig. 9** **a** Final thematic map produced for the study area using proposed method. **b** Coral reef map generated from QuickBird satellite imagery for the same area (Kabiri et al. 2013a, b). Both maps are prepared in UTM Zone-40 coordinate system

than 28 %, when the bleached corals are covered by algae (Kabiri et al. 2013b). The limitations made by atmospheric conditions such as haze and clouds cannot be an obstacle to perform the proposed method, however they are the most adverse objects on the satellite images. Another advantage of the applied method is that it is quite quicker with lower cost compared with direct field observations. Additionally, the proposed method is less sensitive to wind speed as well as cheaper than using meteorological balloons, where the helium gas is usually expensive and inaccessible everywhere. Drones also are expensive and need experts to control and planning the flight. The photos taken by proposed technique are quite more appropriate than the ones taken by kite, because they are prepared manually and the photographer can manage to take them in best situation and from most desired habitats.

On the other hand, a disadvantage of the proposed method is that it needs much more flying time to cover a large of coral reef area (for example some hours), while a scene of high resolution satellite image (such as WorldView-2) may cover and record the same area within few seconds. Additionally, it may be tough to implement this technique in remote islands, where it is rare to access parasailing boats and other required facilities. High turbid waters, sun glints in the surface of water as well as variation in flight height caused by changes in winds and boat speed are other parameters which may limit the accuracy of final produced map by applying this method. Furthermore, wind speed and direction, tidal situation of study area, and depth of corals located are other factors may limit the fulfillment of proposed technique.

## Summary and conclusions

Parasailing photography as a novel methodology was tested for mapping near-shore coastal habitats with particular attention to the coral reef communities. Overall and overlapped taken photos were modified and mosaicked to prepare an integrated map from the types of corals after applying geometric corrections on photos and geo-registration processes. The method shows its capabilities to differentiate coral types as the significant advantage compared with remotely sensed satellite imagery. In comparison with other alternative methods, low cost, ease of implementations, as well as having no sensitivity to atmospheric condition and its ability to produce high accurate thematic maps were the other advantages of the applied method; whereas, inaccessibility to implement flight in remote islands, sensitivity to water quality, sun glints effects and errors raised by variation in wind and boat speed were unfavorable constraints that may decrease the quality of the final results. It can be concluded that this method could be employed where it is necessary to monitor and map the corals in shortest period of time and with lower costs. The method is particularly applicable in emergency cases such as bleaching

phenomena or huge storms causing branching corals to be destroyed in a vast area and where the field observations are costly and satellite images are not available due to the effects of limitative parameters such as clouds and atmospheric conditions.

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