UAS DATA ACQUISITION PROTOCOL FOR MARINE HABITAT MAPPING: AN ACCURACY ASSESSMENT STUDY

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ABSTRACT:

Marine habitat mapping is essential for updating existing information, preserving, and protecting the marine environment. Unmanned Aerial Systems (UAS) are an important tool for monitoring and mapping coastal and marine environment because of their ability to provide very high-resolution aerial imagery.
Environmental conditions have a critical role in marine mapping using UAS. This is due to the limitations of UAS surveys in coastal areas, i.e. the environmental conditions prevailing in the area. The limitations of weather and oceanographic conditions affecting the quality of marine data led to the creation of a UAS protocol for the acquisition of reliable marine information. The produced UAS Data Acquisition Protocol consists of three main categories: (i) Morphology of the study area, (ii) Environmental conditions, (iii) Flight parameters. These categories include the parameters that must be considered for marine habitat mapping.
The aim of the present study is the accuracy assessment of the UAS protocol for marine habitat mapping through experimental flights. For the accuracy assessment of the UAS protocol, flights on different dates and environmental conditions were conducted, over a study area. The flight altitude was the same for all the missions, so the results were comparable. The high-resolution orthophoto maps derived from each date of the experiment were classified. The classification maps show several differences in the shape and size of the marine habitats which are directly dependent on the conditions that the habitats were mapped. A change detection comparison was conducted in pairs to examine the exact changes between the classified maps.
The results emphasize the importance of the environmental conditions prevailing in an area during the mapping of marine habitats. The present study proves that the optimal flight conditions that are proposed of the UAS Data Acquisition protocol, respond to the real-world conditions and are important to be considered for an accurate and reliable mapping of the marine environment.

1. INTRODUCTION

Marine habitat mapping is essential for updating existing information, preserving, and protecting the marine environment. Remote sensing methods are usually used for the acquisition of marine information. A plethora of methods and techniques are available for mapping marine habitats, like satellite images, underwater sampling, and images, manned aircraft, UAS. The method selection depends on the extent of the area, the resolution, and the level of details that are required. Satellite data are commonly used in remote sensing applications as they offer a range of resolutions (Hedley et al., 2016) and some of the products are freely available to the users. However, satellite imagery cannot provide centimeter spatial resolution (Ventura et al., 2018) and most of the time satellites images are not provided timely.

Detailed information is very important in challenging environments, like the marine. UAS is an important tool of remote sensing the last years (Colomina and Molina, 2014) as they can fly in low altitudes and provide detailed information through very high-resolution orthophoto-maps and 3D models. Their use is increasing constantly as the results of the UAS data deliver high positioning of field observation and the produced high-resolution imagery can’t be generated elsewhere. UAS are already used in many coastal and marine applications (Klemas, 2015), as monitoring and mapping marine habitats (Casella et al., 2017; Gonçalves and Henriques, 2015; Gonzalez, 2015; Ventura et al., 2018), detection of marine litter (Deidun et al., 2018; Topouzelis et al., 2019), coastline changes (Topouzelis, Papakonstantinou, and Pavlogeorgatos, 2015; Casella *et al.*, 2016; Su and Gibeaut, 2017; Topouzelis, Papakonstantinou and Doukari, 2017), coastal management (Papakonstantinou et al., 2017).

Although the UAS is very popular in aerial surveys in the marine environment, many challenges and limitations have to be overcome for successful UAS flights (Doukari et al., 2019; Duffy et al., 2018). These challenges and limitations are related to the environmental conditions prevailing to the area during a UAS flight, the UAS specifications and parameterization, and flight planning. The parameters that affect the aerial surveys in the marine environment have been referred in the literature (Duffy et al., 2018; Finkbeiner et al., 2001; Joyce et al., 2018; Vize and Coggan, 2005) and have been summarized in a protocol for UAS data acquisition (Doukari et al., 2019).

Environmental conditions are an important part of aerial surveys that must be considered before and during the UAS data acquisition. Parameters that exist and affect the column between the height of the UAS and the seabed must be considered before a UAS flight. For example, wind speed, waves, and sun glint are commonly affecting the marine environment and the quality of the acquired information, as they interact with each other and they are visible on the sea surface. The wind causes the waves on sea surface which in combination with sun glint presence creates white areas on the images preventing the seabed visibility. This problem has led to limiting flight times to avoid

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the presence of sun glint (Joyce et al., 2018; Mount, 2005). The UAS Data acquisition protocol suggests values of these parameters and flight times to avoid during a day, for aerial surveys in coastal areas (Doukari et al., 2019).
In this study, some of the weather parameters are used in a coastal area to examine the accuracy of the UAS data acquisition protocol.

In this study, a change detection method is used to compare marine habitat orthophoto-maps, in an area, which were acquired on different days with different environmental conditions. This comparison aims to emphasize the importance of the environmental conditions, prevailing in the area during a UAS data acquisition, for the quality and accuracy of the data. In addition, the results of the comparison prove that the UAS Data Acquisition Protocol is an important tool to deal with the limitations of the UAS in the marine habitat mapping.

2. MATERIALS AND METHODS

2.1 Study Area

The selected study area is a coastal area in the middle east part of Lesvos Island, in Greece. The area was chosen as it is easily accessible, four kilometers from the town of Mytilene, with interesting seagrass patches to be mapped.

Figure 1 Study area

2.2 UAS Data Acquisition Protocol

The need for the collection of detailed data using close-range Remote sensing methods in the marine environment led to the necessity of a UAS Data Acquisition Protocol. The purpose of the protocol is to provide solutions to UAS limitations in mapping and monitoring the marine environment by proposing effective techniques for flight planning. The parameters of the protocol are related to environmental conditions, mainly due to weather and sea state conditions prevailing in the study area during a UAS flight, the flight parameters, and the morphology of the study area (Doukari et al., 2019).

The produced UAS Data Acquisition Protocol consists of three main categories: (i) Morphology of the study area, (ii) Environmental conditions, (iii) Flight parameters. These categories include the parameters that must be considered for marine mapping to acquire reliable and accurate data.

The UAS protocol also contains proposed thresholds for every parameter to exclude outlier values. For example, wind speed higher than 3.3 m/s is not recommended for mapping marine environment. The thresholds were derived from the theoretical research, the UAS specifications, and empirical data from test missions over marine areas (Doukari et al., 2019).

In this study, parameters from the second category (Environmental Conditions) of the protocol have been chosen to be examined. These parameters are the wind speed, wave height, sun glint effect, air temperature, and precipitation probability. The proposed thresholds of these parameters are, wind speed equal and lower than 3.3m/s, wave height equal and smaller than 0.5 m., a solar angle between 24 to 45 Celsius degrees to avoid sun glint and sufficiently illumination of the seabed (Finkbeiner et al., 2001; Mount, 2005), air temperature lower than 38 Celsius degrees and precipitation probability lower than 50%.

2.3 UAS Data Acquisition

The UAS flights were performed using a DJI Phantom 4 Pro system and the flight height was chosen at 90 meters from the ground. The images were acquired in a nadir position and their overlap was set at 80% forward overlap and 70% sidelap. Three UAS flights were performed in the area on three dates with different weather conditions. The direction of the UAS flight path was set +- 180 degrees of the solar azimuth angle to avoid the sun glint effect.

The first flight was conducted on 16/04/19, at 10:39 a.m. The sky on that day was clear, with 16 Celsius degrees temperature, 4m/s wind speed, the wave height was calculated at 0.71m and the precipitation probability was 0%. The solar elevation angle on that time was 44.98 degrees and the azimuth angle 119.58 degrees.

The second flight was conducted a day after on 17/04/19, at 3:38 p.m. The sky was clear, the temperature 17 Celsius degrees, the wind speed 2m/s, and the wave height 0.4m, the precipitation probability was also 0%. The solar elevation angle was 46.97degrees and the azimuth angle 238.23 degrees.

The last flight was conducted on 18/04/19, at 2.36 p.m. The sky was partly cloudy on that day, the temperature 18 Celsius degrees, the wind speed 6 m/s and the wave height 1.09 m. with a 0% precipitation probability. The solar elevation angle was 56.25 degrees and the azimuth angle 218.71 degrees.

According to the proposed thresholds, on the first date (16/04/19), the wind speed and wave height are higher than their threshold values. On the second date (17/04/19), all the parameter values are within thresholds besides the solar elevation angle which is a bit higher than 45 degrees. On the third date (18/04/19), the wind speed, wave height, and solar angle are higher enough of the proposed thresholds.

2.4 Methodology

The aerial images of the different acquisition dates were processed for the generation of high-resolution orthophoto-maps using Structure from Motion (SfM) algorithms, in Agisoft Photoscan.

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The methodological workflow consists of four basic steps. The first step is the visual inspection of the orthophoto-maps and the selection of regions of interest, the second step is the isolation of the regions, the third step is the classification of the orthophoto-maps and the last step the change detection comparison of the classified images.

The orthophoto maps were visually inspected to find differences between them and to detect regions of interest to use as comparison objects. The differences were visually obvious in parts of the orthophoto-maps. An area with seagrass patches, with an interesting circular shape in different sizes, was chosen for the comparison between the different orthophoto-maps.

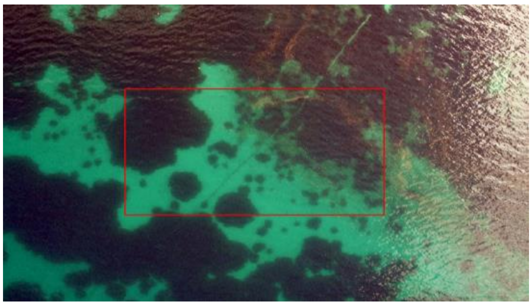

Figure 2 Selected subset on the orthophoto-maps.

The chosen regions were isolated and extracted as vector polygons using an R programming language script. Having the polygons of the regions, the orthophoto-maps were masked, and new images extracted as results of the first step. The new images have values only on the selected regions while the rest of the image has no values (Figure 3).

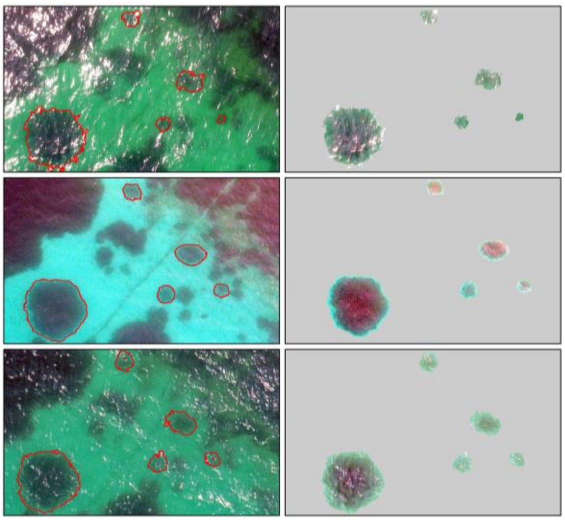

Figure 3 The polygons of the regions of interest (left) and the masked images (right)

The images of all dates were then classified using ISODATA unsupervised classification in ENVI, with two classes. The classifier first calculates the class means evenly distributed in the image. Then creates clusters of the remaining data using minimum distance methods. This procedure is repeated until the percentage of changes is less than a selected threshold value or the maximum iterations number is reached. The classification method created a class with the regions that we are interested in comparing and a class with the rest of the image values that will not be used.

The classified images were then used for Change Detection comparison in ENVI. The maps were compared in pairs. As a reference map, we used the orthophoto-map from the second acquisition date (17/04/19), which shows better the shape of the selected regions. That orthophoto-map is also clearer visually, without sun glint areas. The comparisons resulted in different images, polygons, and statistics of changes.

3. RESULTS AND DISCUSSION

The orthophoto-maps generated from the aerial images showed significant differences on the different dates. The orthophoto-map of 16/04 has intense sun glint areas on the left of the map, which are shown as white areas (Figure 4). These areas in combination with the wavy surface blur parts of the map and prevent the visibility of the seabed. Some of the selected seagrass patches are not easily distinguished from the neighbor species. The wavy surface can be explained by the wind speed and wave conditions prevailing in the area during the image acquisition. The values of these parameters were higher than those suggested in the UAS protocol. The solar angle was marginal within the suggested angle range. This can explain the sun glint areas which are favored by wind conditions.

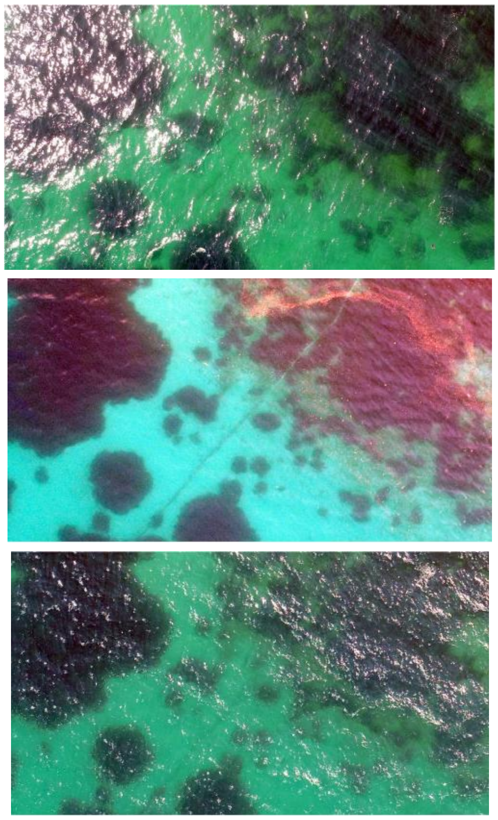

Figure 4 Subsets of the orthophoto-map on 16/04/19 (top), 17/04/19 (middle), 18/04/19 (bottom).

The orthophoto-map of 17/04/19 (Figure 4) is clearer than the one of 16/04/19. The sea surface is calm with small wrinkles that do not seem to affect the acquisition of marine information. This can be explained by the wind speed and wave height values on that date, which were low and within the suggested thresholds. There are not sun glint areas, although the solar angle was bigger than the suggested angle range. We assume that this is due to the lack of wind and waves during data acquisition. While the weather conditions on that date seem optimal according to the UAS protocol, the orthophoto map is a little blurred. This could be the result of increased water turbidity on that day, but it does not seem to affect the distinction of the marine habitats.

The orthophoto-map of 18/04 (Figure 4) has also some sun glint areas on the right of the map and some on the left. The sun glint areas seem fewer than that on the 16/04 map. The sea surface is wavier than the map on 16/04 which seems reasonable if we consider that the wave and wind values were the highest on that date. The distinction of marine habitats could be challenging in some areas of the map.

The first results of the visual comparison between the subsets of different dates have several differences that can be explained logically given the weather conditions in the area during data acquisition. Subsequently, these differences will be quantified using a change detection algorithm as it results in visualization and percentages of differences.

The classified images show many differences in the distinction of the regions of interest (ROI). The ROI used in the present study has been classified, using ISODATA unsupervised classification, in green colour and the rest of the image in red colour.

On 16/04, it is observed that the shapes of the regions have been affected by the sun glint areas that make them rougher than they are with some gap areas in the bigger region. On 17/04 the regions are better outlined, and almost solid without gaps. On 18/04, the regions seem bigger enough than their real areas, which is probably because of the waves on sea surface that makes the distinction of the regions difficult.

The total pixel count of the regions of interest on date 16/04 is 63.787, on date 17/04 is 72.298 and on date 18/04 is 75.640, in a total image pixel count of 680.988. We assume that the selected regions' shape is better described by the 17/04 orthophoto-map. This emerges from the fact that the orthophoto-map on 17/04 is clear and the distinction of the regions more accurate.

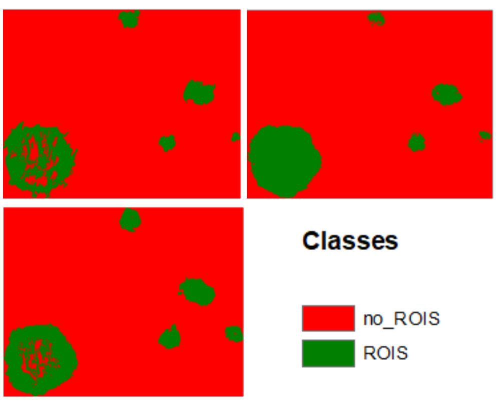

Figure 5 Classified images using the ISODATA unsupervised classification. Top left: 16/04, Top Right: 17/04, Bottom left: 18/04.

For the change detection method, the classified image of 17/04, was used as a reference image. The first comparison pair resulted in 8.115 pixels of change and a percentage of 1.19% change from 17/04 to 16/04. In Figure 6, the regions of the dates 17/04, 16/04, and their changes are visualized. The regions of 16/04 are visualized in blue line polygons, the regions of 17/04 in solid polygons, and their changes in purple.

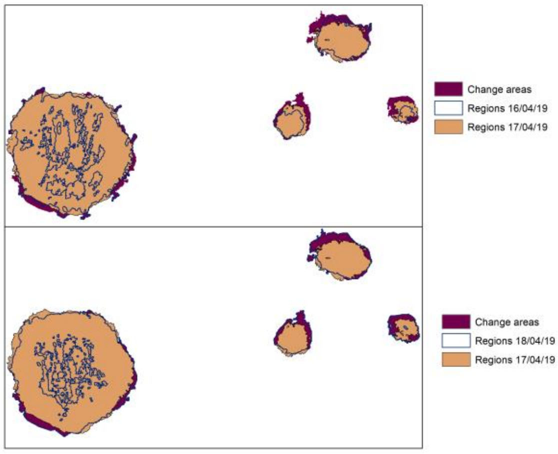

Figure 6 Visualization of regions on dates 16/04, 17/04 (top), 18/04, 17/04 (bottom), and their change areas.

The second comparison pair resulted in 17.016 pixels of change and a percentage of 2.50% change from the classified regions on 17/04 to 18/04. In Figure 6 the regions of 18/04, 17/04, and their changes are visualized. The regions of 16/04 are visualized in blue line polygons, the regions of 17/04 in solid polygons, and their changes in purple.

The changes of the second comparison pair are bigger than the first, this is because of the regions on 18/04 which consist of a bigger count of pixels than the regions of the two other dates. Considering that on 17/04, the shapes of the regions are outlined better, we assume that the conditions on 18/04 led to the worst result on habitat mapping.

4. CONCLUSIONS

The results showed many differences in the selected regions on the shape and pixel count, in the three different orthophoto-maps of the study area. The differences are mainly due to the different weather conditions prevailing in the area during the aerial images acquisition. In this study, the three of the five parameters which were examined (wind speed, wave height, sun glint effect, air temperature, and precipitation probability) had higher values than the suggested thresholds of the UAS Data Acquisition Protocol.

On the first date (16/04), the wind speed and wave values were higher than the threshold values. In the orthophoto-map of this date, the sea surface was wavy with sun glint areas. On the second date (17/04), all parameter values were within the thresholds, except the sun angle which was a little bigger than the suggested. The orthophoto-map on that date is a little blurry, without sun glint areas and the sea surface is calm. On the third date (18/04), the wind speed, wave height, and sun angle values were higher than the thresholds. In the orthophoto-map of that date, the sea surface is wavy and there are some sun glint areas.

The parameters air temperature, precipitation probability had lower values than the suggested thresholds at all dates.

The visual comparison showed many differences in the three orthophoto maps which can be explained considering the weather conditions on its date. For example, on both 16/04 and 18/04, the sea surface is wavy because of the high values of wind speed and wave height. The sun glint effect is also favored by the existence of waves. These parameters interact with each other and affect the result of the maps. The blur effect in the 17/04 orthophoto-map could be the result of high turbidity values on that day. Oceanographic parameters may as well affect the data acquisition over the marine environment and should be considered. Differences were also observed in the selected regions of interest as to the shape, extent, and color.

The classified images had many differences as to the shape of the classified regions as well as their pixel counts. The shapes of the regions were better described on the 17/04 image, while on the other two dates, the shapes of the regions were included edges and areas from sun glint parts of the image. This led to false classification results and pixel counts. This comparison could be more accurate if we had size measurements of the selected seagrass patches which were used as ROI.

The change detection method showed that the comparison between 17/04 and 18/04 had more changes than the comparison between 17/04 and 16/04. This seems reasonable as the size of the regions on 18/04 was in total bigger than the other two dates. These differences prove that incorrect mapping can lead to erroneous conclusions about the extent of the habitats.

In conclusion, environmental conditions have a critical role in marine habitat mapping. The quality and accuracy of aerial mapping in the marine environment are directly affected by the conditions prevailing in the area during the data acquisition. Parameters like waves and sun glint could lead to wrong classification results and measurements of the extent and the exact position of important marine habitats. The change detection comparison of time-series data could lead to wrong conclusions of marine habitat evolution if the conditions during data acquisition are different. The UAS Data Acquisition protocol is an important tool for the acquisition of reliable and accurate marine information.

The next steps require the use of *in-situ* data (measurements of the regions of interest - underwater images) and accurate field measurement of the oceanographic parameters. More information in the field data will reveal the most effective parameters for the marine habitat mapping and will evaluate the selected thresholds of the protocol for their efficiency in the real world.

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