Reviewed: 7/27/2021

Low-cost mapping of intertidal reefs using side-scanning sonar and UAV systems

Mustafa Mokrech, George Guillen and James Yokley

Environmental Institute of Houston and College of Science and Engineering, University of Houston-Clear Lake

Houston, Texas 77058

Background and Objectives

Oyster reefs provide important environmental services including water filtration and purification, protection of seagrass beds and saltmarshes from wave action, forage for some invertebrates and finfish, wading birds, and habitat for numerous marine organisms including commercially and recreationally important finfish. Mapping the physical extent and conditions of these reefs provides scientists and managers with data on the current status of oyster populations and hard bottom habitat within an estuary as well as information needed for ongoing oyster conservation and restoration efforts. Mapping intertidal shallow reefs are usually impeded by the inability to use traditional subtidal side scan sonar and survey methods. This ongoing research project aims to apply side-scanning sonar system (subtidal water depth 0.9-1.5 meters) combined with drone (also known as Unmanned Aerial Vehicle, UAV) photography (for shallow water where water depth < 0.9 meters) together with digital image processing techniques to map selected intertidal oyster reefs and shell bottom.

Study Sites

The following criteria were considered when selecting our two primary sites (Fig 1) for conducting this research: 1) sufficient water depth to allow easy and safe navigation of a small boat equipped with side scanning sonar system to the site; 2) high potential for aerial exposure of the reef sites due to low tides or wind driven winter storm systems; and 3) sites that are distant from airports to comply with all Federal Aviation Administration (FAA) flight restrictions. A third site (Site 3) did not satisfy the last criterion but is currently under consideration due to its high ecological importance and we are communicating with FAA to gain future flight approval.

Methods and Initial Results

Side-scanning sonar: Transect routes were established to capture sonar images that were partially overlapped to ensure no gaps existed in the final products as well as videos for comparison purpose. Side scan images were captured using a Humminbird Model 1197c with a XHS 9 HDSI 180 T Transducer attached to a small draft aluminum boat or kayak (Fig 2 & 3). Data collection was conducted during calm wind and at approximately high tide time to ensure proper functioning of survey equipment in shallow water. Post processing was conducted using SonarTRX and ArcGIS (Example is shown in Fig 4).

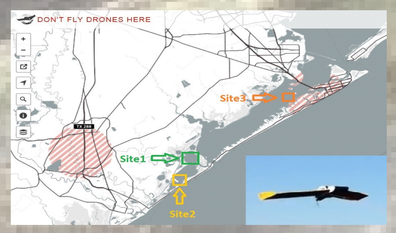

Fig 1. Three sites are considered: Site1 is already surveyed; Site 2 is scheduled to be surveyed; and Site 3 is considered for survey subject to FAA approval.

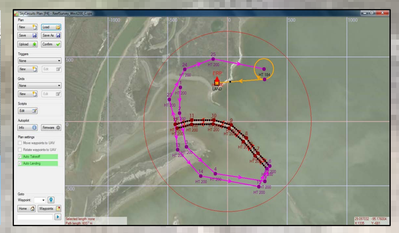

Fig 6. A flying acquisition plan in the Bastrop Bay shows the flying path that includes the launching and navigation part, surveying path along the reef and the navigation part to landing.

Fig 2. Operating the side-scanning sonar system with a transducer installed in the front of a small vessel.

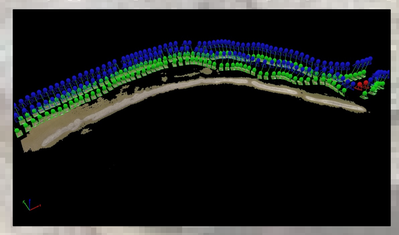

Fig 7. Densified point cloud: green dots indicate where the UAV is, blue dots where the UAV should be at the time of the image capture, and red dots indicate discarded data.

Fig 3. Operating the side-scanning sonar system in shallow water from a kayak.

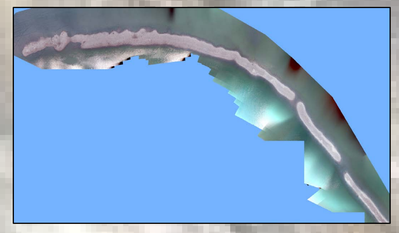

Fig 8. 2D orthoimage of the data acquired using UAV at 200ft altitude: the spatial resolution is 2.2.

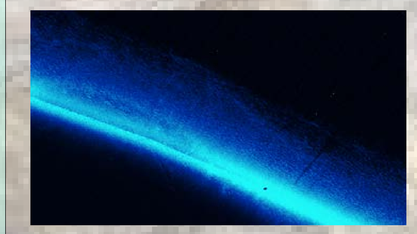

Fig 4. Mosaic of the sonar images collected using the side-scanning sonar system. The processing is conducted using SonarTRX software.

Fig 9. Closer display of part of the orthoimage showing the level of details captured by the UAV camera.

Fig 5. Field data collection of the reef composition at 10m×10m site using 20 random samples.

Fig 10. Inspecting the composition of live oyster, dead oyster and shell hash within 1m×1m quadrat. 9199

Contact for further information and questions

mokrech@uhcl.edu

Drone Photography

The low-cost low altitude (200–300ft) photography using a Quest UAV (Aqua) with a photogrammetric system was used to acquire high-resolution images for mapping intertidal reefs at a reasonable cost (Fig 1). The collected images were digitally processed using Pix4D software to produce an ortho-image using a workflow that includes establishing the orientation of images, key points, image matching, and point cloud densification. The final product (Fig 8 & 9) was a 2.2 cm spatial resolution image where the reef extent can be clearly identified and mapped. The investigation of reef composition is underway using both visual interpretation and digital image processing that includes hard and soft classification using the ArcGIS and IDRISI platforms. Training data collected using 20 random quadrats (1m×1m) within 10m×10m area (Fig 5 & 10) was used. In addition, the composition within 1m×1m quadrats at additional sites in different locations on the reefs were used for validation purposes.

Conclusions and Further Analysis

1. Drone photography can be used in mapping the extent of intertidal reefs during extreme low water levels during full/partial exposure of reefs.
2. The spatial distribution and shapes of reefs must be considered during the planning process of UAV flights as sufficient key points must exist in each aerial image in order to conduct successful digital image processing of the collected data.
3. The side-scanning sonar system is useful for mapping the extent of shallow reefs. The sonar images may overlap with the images collected by drones.
4. Analyzing the composition of oyster reefs is a challenging process in digital image processing as submerged and exposed reefs produce different signatures. Further analysis in this regard combined with visual image interpretation in still underway.
5. The logistics for acquiring aerial images using drones can be challenging over shallow waters. Using the right operational platform (e.g. air boat) for water transport is essential
6. Although acquiring FAA permits to operate UAVs is time consuming, the return value of this technology can be significant.

Acknowledgments

We would like to thank the Gulf Coast Prairies LLC for funding this project. We also appreciate all the assistance in the field from the staff and graduate students at Environmental Institute of Houston, UHCL.