University of New Haven
SURF 2018

Using Low Level Aerial Imagery to Assess Fiddler Crab (*Uca pugnax*) Populations in Salt Marshes

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Introduction

Coastal salt marshes are dynamic systems experiencing changes in tidal inundation, habitat loss and species distribution (e.g. Gedan et al. 2011, Zajac et al. 2017). A variety of factors can influence species inhabiting salt marshes including salinity, nutrient loads, wave action, and soil chemistry. These factors can influence both plant and animal distributions, including the distribution of fiddler crabs (Bertness 1992). Fiddler crabs are an essential component of northeast salt marsh systems; they act as a food source for birds, other species and for turnover in marsh soils (Bertness and Miller 1984). This soil turnover can re-oxygenate the soils, allowing for easier uptake of nutrients by plants (Thomas and Blum, 2010). Sea level rise (SLR) is an increasing concern for salt marsh habitats. SLR effects on salt marsh geomorphology and plant communities are being increasingly studied (Luk and Zajac, 2013, Warren and Niering 1993), but the effects on animal distributions are less known. It is critical to understand how SLR is affecting both salt marsh habitats and the animals that live there. This work focused on assessing fiddler crab, specifically *Uca pugnax*, populations on marshes that are changing due to SLR.

Previous studies have examined fiddler crab populations using traditional on-ground methods using transect and quadrats to capture and record crab abundances. New unmanned aerial vehicle (UAV or drone) technology allows us to examine fiddler crabs and salt marsh habitats from a different perspective to try and quantify salt marsh conditions as well as distributions of fiddler crabs (Klemas, 2015). UAVs can be a cost effective way to create high quality images and maps that have a resolution capable of capturing individual crabs to be counted. UAV mapping methods are being increasingly used to help resource managers, surveyors, farmers, scientists and policy makers (Madden et al. 2016). UAVs are beginning to be used to assess salt marsh habitats and organisms. UAV low level imagery could allow for more accurate estimates of patch use by fiddler crabs as well as their spatial distributions, and the effects of changing marsh habitats.

I used low level aerial imagery from a UAV to assess its utility for assessing crab populations in specific types of salt marsh patches. A previous study (Zajac, *in preparation*) showed that fiddler crabs can be recorded by drones flying at low altitudes. Fiddler crabs live on a variety of habitat types in salt marshes including bare ground, pools, creeks, banks and vegetation. UAV imaging could be more effective for assessing crabs in unvegetated habitat types and was the primary focus of this study. Typically fiddler crab densities have been shown to be high in creek bank areas while decreasing on the high marsh. It is important to understand that accurate counts and assessments can only be made if the fiddler crabs are undisturbed. UAVs may provide a noninvasive method for examining the salt marsh as long as the noise, shadow and downdrafts produced by the drone do not affect the crabs' behavior.

Materials and Methods

The primary study areas for this protect were Banca and Pleasant Point marshes located in Branford, CT. Chaffinch marsh was also studied but data was not included. These sites have been studied previously by undergraduate and graduate students working with Dr. Roman Zajac. These studies serve as baselines to allow comparisons of fiddler crab population over time between this study and those in last few years.

Aerial imagery was collected using a DJI Phantom 4 and DJI Phantom 4 Pro UAVs over predetermined flight paths approximately every other week over the study period. Preliminary flights were conducted to observe the effects of the UAV on the fiddler crab behavior and determine a minimum height for which the UAV can fly without causing any abnormal behavior patterns. Initial flight heights were at 5- 10 m above the high and low marsh areas, and provided accurate images for assessing populations. Flights flown at lower altitudes produced images that were difficult to orient in the Agisoft software. These flights took more computer memory then we had available to process and would not create enough tie points to create an accurate model. Spatial references were also created in Agisoft by converting the created orthomosaic into a TIFF file containing GPS location points. These references allowed for accurate assessment of images using GIS spatial analysis. The drone was controlled using Pix4d and Drone Deploy Apps to obtain pictures and GPS data in order to georeference the data within GIS. Using the UAV imagery, the photos were oriented within Agisoft, creating an orthomosaic that was used to determine habitat type, the number of crabs, and the habitat characteristics in each image (Figure 4). The orthomosaics were analyzed using Image J/ FIJI image analysis software and the trainable Weka plugin. The Weka plugin allowed for determining the areas of salt marsh habitats with no vegetation within which the crabs were counted. Once those areas were determined, the number of crabs in each were counted.

Data on crab abundances, patch types and areas, and perimeters were analyzed using NCSS to assess patch occupancy, abundance differences among areas and relationships with patch size. ArcGIS was used to assess spatial patterns in crab abundances among bare patches in each survey area.

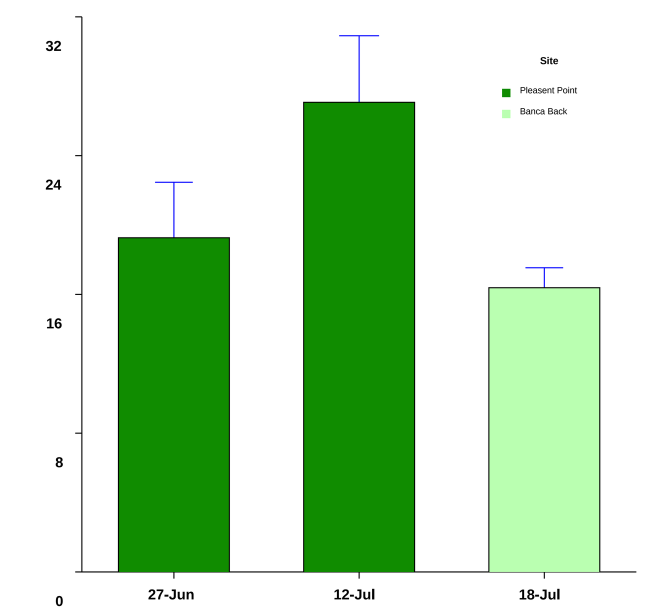

Figure 1.

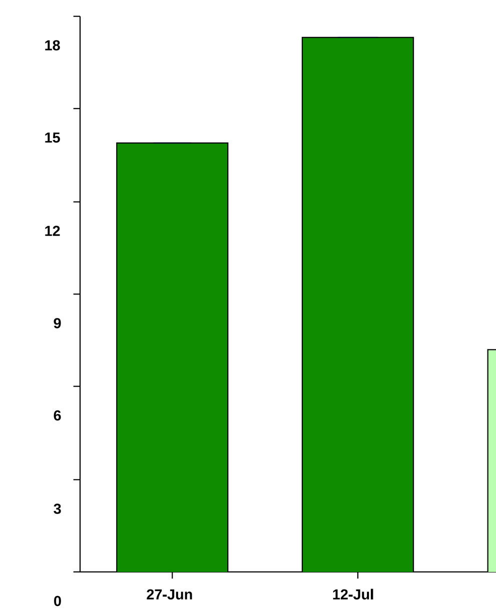

Figure 2.

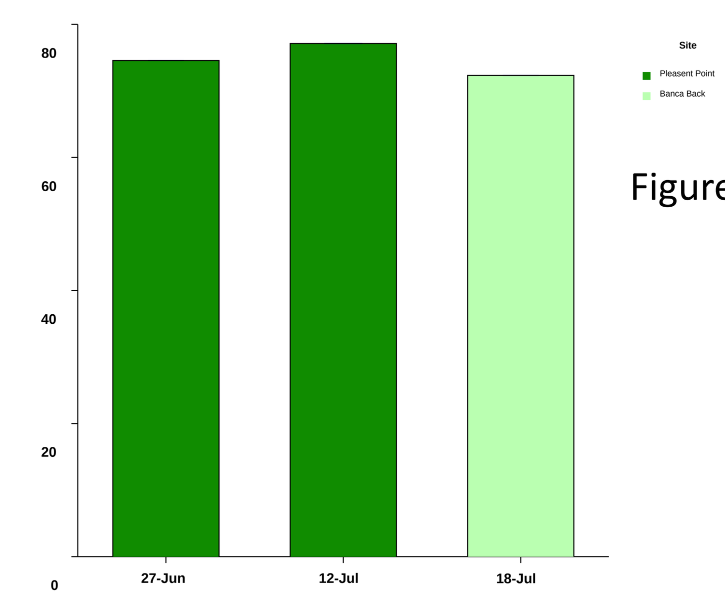

Figure 3.

Figure 4.

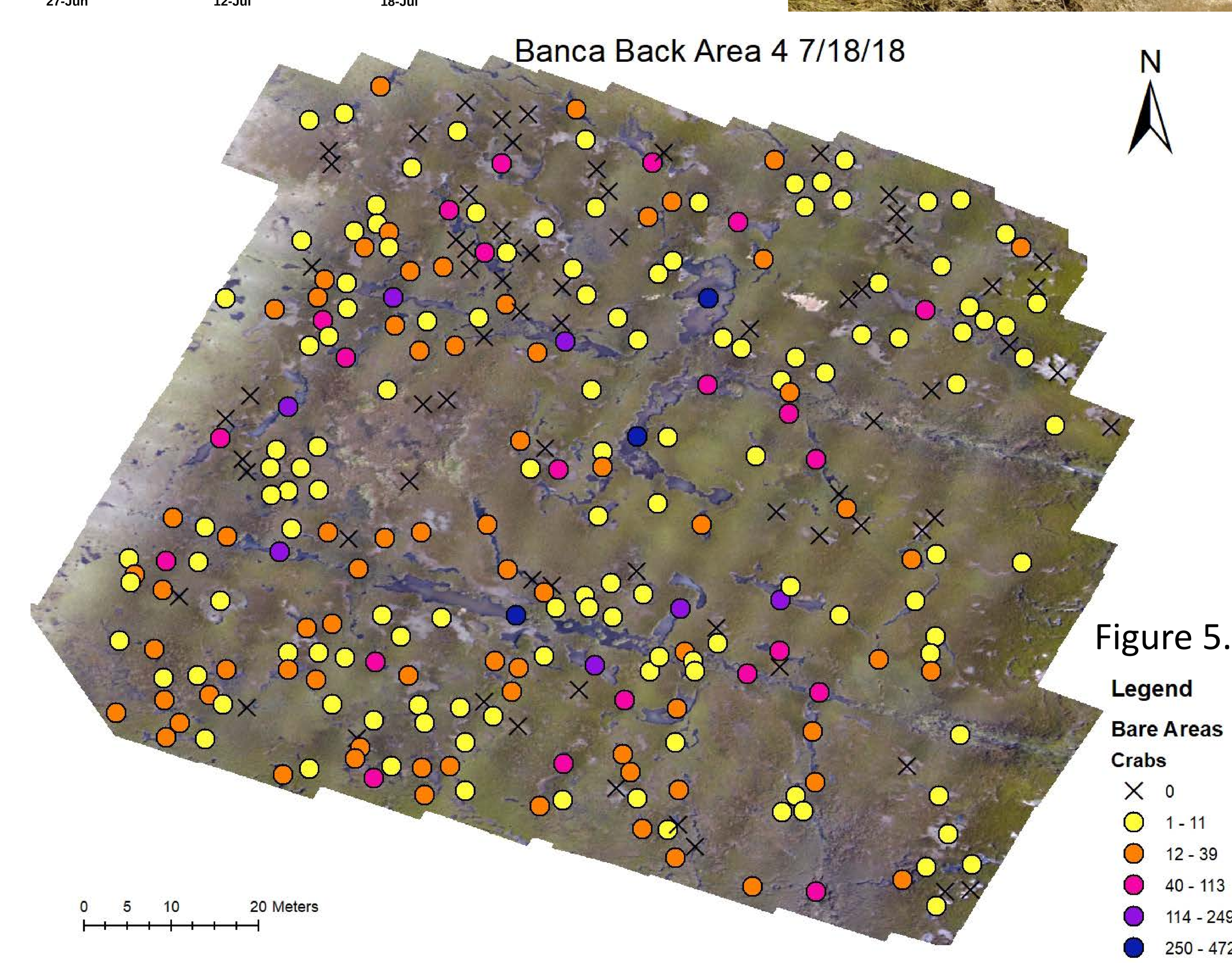

Figure 5.

Results

* The total area analyzed in this study was 26,283.8 m^2. Of this area, bare patches were found to cover 13.8% (6/27) and 17.3% (7/12) of the study areas in Pleasant Point marsh. In Banca Back, bare area was found to be 7.2% (7/18), less than that of Pleasant Point (Figure 2).

* Approximately 80% of all bare areas, at all sites, were occupied by crabs (Figure 3).

* Crab density at Pleasant Point was found to be ~19 crabs/m2 (6/27) and ~26 crabs/m2 (7/12). At Banca Back, the density was found to be ~16 crabs/m2 (7/18). Pleasant Point on 7/12 had the highest density of crabs, which was statistically significant from both other values (Figure 1).

* Spatial autocorrelation analysis in GIS indicated that crab abundances in bare patches within the study areas had a random spatial distribution (Figure 5) except for Area 3 of Banca Back. Banca Area 3 was located closest to both the main tidal creek in the marsh, and there was a significantly clustered distribution of bare areas that had high crab abundances.

Conclusions

Low level aerial imaging with a UAV was successfully used to map salt marsh habitats and obtain data on fiddler crab (*Uca pugnax*) abundances in bare areas (patches). During the initial flights of the project, the drone was flown at varying heights (5-15 m) to find an optimal height for capturing high resolution images of the crabs while making sure not to elicit an escape response. At a height of 5 m, the image resolution allowed for assessment of fiddler crab sex. However, only the Pix4D app allowed for flight plans below 10 m. Flying the drone free hand or without using the survey apps was possible, but hard to maintain a flight path and take photos with approximately 60% overlap.

Flight plans at 10 meters were found to be optimal in terms of flight time, total area processed, low interference with crab behavior, and ability to accurately count crab populations. At a 10 m flight altitude it was possible to fly a 307 m^2- 7,228 m^2 area in about 10-20 minutes and with just one UAV battery. Two weather conditions that had a noticeable effect on image quality and the orthomosaic produced, was the wind and sun. Sun glare was present in photos that were taken in the later afternoon (~ 4:00 pm). Increased sun glare led to inaccurate camera positioning in the software used to create the orthomosaics, making them unusable. Even when sun glare did not interrupt the camera orientation process it made it more difficult to find crabs and distinguish them from the patch within the orthomosaic being analyzed. Using UAV data collection methods could allow for easier and non-invasive approach to analyzing salt marsh patches and possibly vegetation structure. From an altitude of 10 m, crabs were able to be distinguished in both bare ground and pool patches within the salt marsh, but not in vegetated areas.

Crab density was found to be greater at Pleasant Point than in previous studies. On 6/27/18 the mean density of crabs was found to be 19.26 crabs/m^2 , which was higher than densities found in bare patches (6 crabs/m^2) and pools (14 crabs/m^2) by Zajac et al (*in preparation*). At Banca Back the mean density of crabs was similar to that found in (R.N. Zajac, et al.). Data collection in previous research was taken at an earlier time in the summer than our data. This may be responsible for the similarity of mean crab density; more crabs would be found due to the non-invasive approach of a UAV creating a higher mean density later in the season where populations begin to diminish.

Regression analysis indicated that bare patch area accounted for 28.6% of the variation in crab abundances. Other variables analyzed explained less of the variance in crab density within each of the patches. *Uca* densities may be more related to patch conditions and preferential feeding habits in specific substrate types.

The distribution of crabs in bare patches showed primarily random distributions except for the Banca Back (7/18/18) area closest to the main tidal creek. This could have been due to preferential settlement of larvae on bank edges and the accessibility of the tidal bank compared to settlement within the high marsh. Mean *Uca* densities along the creek banks were found to be significantly higher than all other areas with approximately 67 crabs/m^2. However, this study shows that bare patches on high marsh sections of salt marsh provide a significant habitat for fiddler crabs, in which they can reach abundances equivalent to that in low marsh areas, and that UAV technology can be successfully used to study their populations in these types of habitats.

References

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Acknowledgements

Thanks to Nicole Adrion and Amanda Tucker with their help in the field.