Towards Monitoring Saline Wetlands with Micro UAVs

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***Abstract*— Monitoring saline wetlands is an important task for understanding and protecting fragile ecosystems. Unique features of disconnected wetlands suggest that micro UAVs can be used to greatly improve the resolution of salinity maps and help detect elusive saline springs. This paper describes our initial efforts augmenting our water sampling platform with conductivity sensors. We describe our approach to detecting springs: a two UAV team with a thermal camera on one UAV and conductivity sensors on another. We present preliminary results demonstrating the marked increase in spatiotemporal resolution of conductivity maps compared to traditional hand techniques.**

I. INTRODUCTION

Scientists study saline wetlands because they maintain diverse and sometimes endangered organisms, and are under increasing pressure from intensive agricultural practices and residential development. Because of these pressures, water scientists seek to create high-quality datasets of the wetlands properties to establish a benchmark by which to measure future changes. In addition to these conservation goals, basic scientific questions remain unanswered about the spatial and temporal variability of wetland properties.

Our limnologist collaborators study the Salt Creek water networks of Eastern Nebraska, USA, as shown in Fig. 1, home to the federally endangered Salt Creek Tiger Beetle (*Cicindela nevadica lincolniana*), found exclusively in this region. The yellow lines indicate the boundaries of the surface water, which change frequently.

Water scientists study this ecosystem by collecting water samples for lab analysis and measuring water properties *in situ*, mostly using manual hand-sampling techniques.

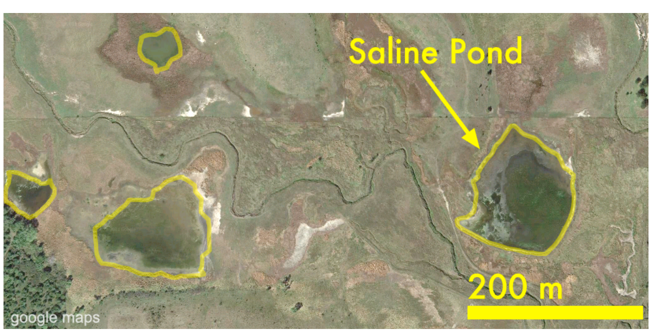

Fig. 1. Little Salt Creek Ponds, Lincoln, NE, USA

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Fig. 2. Aerial monitoring platform with conductivity and water sampling subsystems at Little Salt Creek, Nebraska, USA.

To increase the efficiency, duration, and quality of monitoring, field roboticists have developed a variety of autonomous systems for underwater, surface, and aerial environmental monitoring [1], as well as sensor networks for long term monitoring [2]. Autonomous underwater vehicles (AUVs) monitor for long period with high quality, but the Salt Creek ponds are only 45 *cm* deep during the wet season, with mud and silt that reduce visibility. Autonomous surface vehicles operate in shallow water [3], but the Salt Creek ponds are surface disconnected making it difficult to deploy and redeploy a small boat. Amphibious devices, like Dudek *et al.* AQUA system [4], traverse water, mud, and grasslands, but can trample sensitive plants. A permanent sensor array is expensive and difficult to redeploy when the water levels change. Therefore we have started a new line of work extending our aerial water sampling platform [5] to measure properties of saline wetlands.

Our new line of work has three goals:

1) Increase the spatiotemporal resolution of conductivity (salinity) maps.
2) Allow water scientists to adaptively choose water sampling locations based on aerial-sensed conductivity.
3) Explore a two aerial vehicle system to detect saline springs and obtain water samples for lab analysis.

II. AERIAL PLATFORM

Our aerial water sampler can collect three 20 *ml* water samples from different locations within one kilometer and can be carried and deployed by a single scientist [5]. We are extending our current system by adding conductivity sensors and by adding a second UAV with a thermal camera (see

Sec. IV). Using a UAV allows scientists to quickly visit multiple locations at different ponds and optionally return with water samples. Fig. 2 shows our UAV with both the conductivity sensor and a small water pump at the terminus of a flexible plastic tube.

III. SPATIOTEMPORAL RESOLUTION

Scientist's understanding of these systems is limited by the spatial and temporal resolution of current datasets. We performed preliminary experiments to compare current hand measurements with measurements obtained with our UAV mechanism, and to verify that our instruments had similar calibration. In this experiment, a water scientist performed traditional sampling by using a hand-held conductivity meter and a separate GPS. They started at a saline spring and finished in open water. We repeated these measurements by hand-carrying the UAV mechanism along the same route while continually taking conductivity and GPS measurements. Fig. 3 shows the increased resolution of conductivity readings obtained by our UAV mechanism as compared to measurements made by hand.

The aerial platform continually records water conductivity and GPS information, capturing more data points than existing hand methods. During this experiment, the conductivity sensor went in and out of the water, resulting in suddenly lower conductivity readings which were filtered after the experiment. By collecting more data points, aerial sensing creates maps with higher spatial resolution, and the speed and ease of deployment enables greater temporal resolution. Higher resolution maps can improve scientists' understanding of natural systems by revealing previously undetected phenomenon. In future work, we intend to sample on various timescales to better understand how salinity changes over time.

IV. TWO UAV TEAM

Our limnologist collaborators are especially interested in transient saline springs, which appear and disappear during a season and change location year to year. We have begun to explore a two aerial vehicle configuration to more easily detect and sample from these springs. Fig. 4 shows the approach where one UAV carries a thermal camera, while the other UAV carries conductivity sensors and the water sampling system.

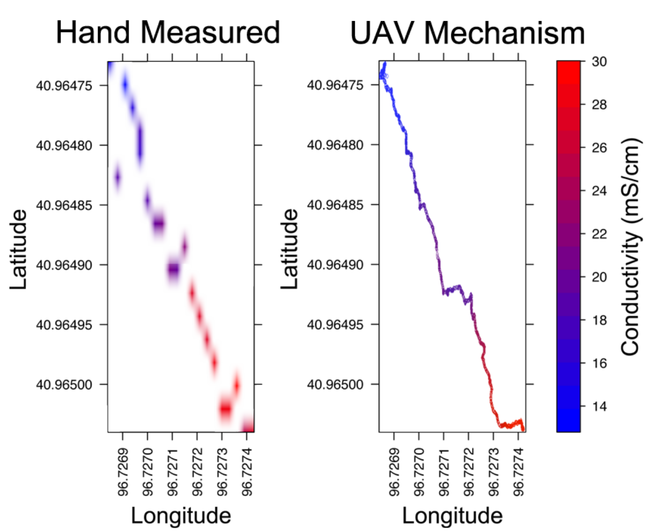

Fig. 3. Comparison of Salt Creek conductivity by Hand and UAV mechanisms.

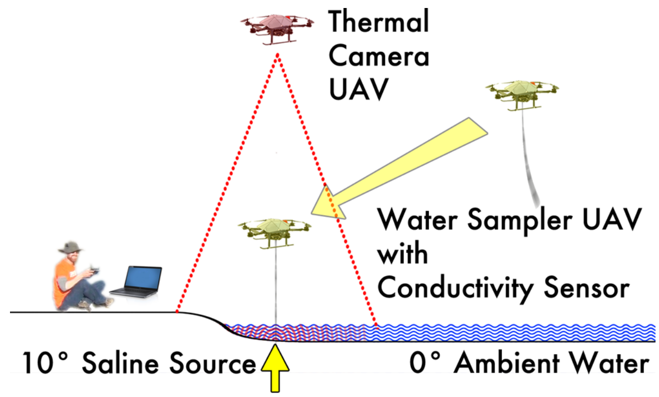

Fig. 4. Two vehicle search for saline spring.

The UAV with the thermal camera flies at 10-30 meters above the wetlands to identify sources of underwater springs. The springs can be detected by temperature because they produce water at ground temperature, 10°C, while the surrounding water is hotter or cooler depending on the season or time of day. Once the location of a spring has been identified, a UAV flying at low-altitude directly measures the conductivity by dipping sensors at the interesting location. If the water conductivity indicates that the spring is saline, then the water scientist can direct the UAV to collect a water sample at that location.

V. FUTURE WORK

In the fulfillment of this work, we plan to explore the capabilities of the UAV system in building high-resolution conductivity maps in small lakes. We also intend to use the conductivity information for adaptive sampling with input from domain scientists. We have also begun to use a multi-UAV team as a system to help ecologists.

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