We identified, located, and tracked soniferous estuarine fishes (in families Sciaenidae, Batrachoididae, Triglidae, and Blenniidae) in a shallow saltwater marsh creek using a seven-element hydrophone array.

Soundscapes from a Saltwater Marsh Creek Captured by a Hydrophone Array

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Introduction

Soundscape recordings allow listeners to determine the presence and activities of soniferous animals in an area (Pijanowski *et al.*, 2011), and these recordings have been used to learn about both terrestrial (Fischer *et al.*, 1997) and aquatic environments (Parks *et al.*, 2014; Luczkovich and Sprague, 2022). If we want to learn about animals that we cannot see, we can listen to them. But most soundscapes recorded with a single hydrophone provide little information about the locations and movements of the sound-producing animals in the recording because hydrophones are omnidirectional at low frequencies. Therefore, we deployed a seven-hydrophone array in a very shallow saltwater creek to learn about the locations of sound producers and their movements.

Methods

The study site was a Clambank Creek, a saltwater creek at the University of South Carolina Baruch Marine Field Laboratory in the North Inlet-Winyah Bay National Estuarine Research Reserve near Georgetown, SC, USA (see Fig. 1). We deployed an array of seven HTI 96-Min hydrophones (High Tech, Inc., Long Beach, MS, USA) in water of depths of 1.00 m to 1.70 m by wading into the water and mounting the hydrophones on rods connected to cinder block anchors placed on the creek bed. (See Fig. 2) The array configuration was sub-optimal with hydrophone locations influenced by bottom conditions and our ability to secure the hydrophone in-place while wading. We determined the hydrophone positions by triangulating to known reference positions using a laser rangefinder and validated them using a Wide Area Augmentation System-enabled Global Positioning System (WAAS-GPS).

To calibrate the array, we produced impulsive sounds underwater at five positions, determined by triangulation of laser rangefinder measurements and WAAS-GPS. We used the delays of the calibration sounds between hydrophones to calibrate the array, solving sound propagation equations for the hydrophone positions.

We recorded sounds using an eight-track simultaneous-sampling digital recorder (Zoom F8, Tokyo) for 24 hours and identified sounds in the recording using knowledge of the fishes ing the estuary (Simpson *et al.*, 2015) and by comparing them to recordings of captive fish. We determined the locations of recorded fish by measuring the signal time delays between each hydrophone and solving acoustic propagation equations for the source position. Calculating the propagation distances from the time delays between hydrophones requires the local speed of sound in the water, which we determined with the UN equation (Wong and Zhu, 1995) using water quality measurements taken every 900 s (15 min) by the Clambank Creek monitoring station located on the small pier in Fig. 2. Sound speed values for times between the 900 s water quality samples were determined using a third-order cubic spline interpolation.

Results

We identified rich acoustic activity in the soundscape recordings, including sounds produced by Atlantic croaker *Micropogonias undulatus*, bighead searobin *Prionotus tribulus*, oyster toadfish *Opsanus tau*, silver perch *Bairdiella chrysoura*, spotted seatrout *Cynoscion nebulosus*, and striped blenny *Chasmodes bosquianus* as well as snapping shrimp (family Alpheidae).

Figure 1: The study site shown on a map of the southeastern United States. (Map generated using Google Earth.)

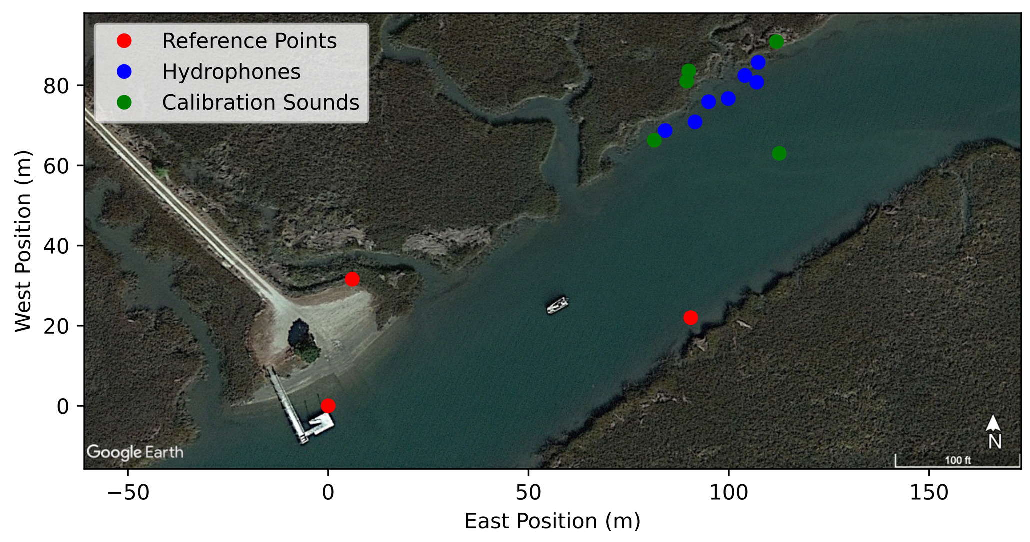

Figure 2: Positions of the reference markers, hydrophones, and calibration sounds at Clambank Creek. The Clambank water quality monitoring station is located on the pier on the bottom-left of the image. (Satellite image obtained from Google Earth.)

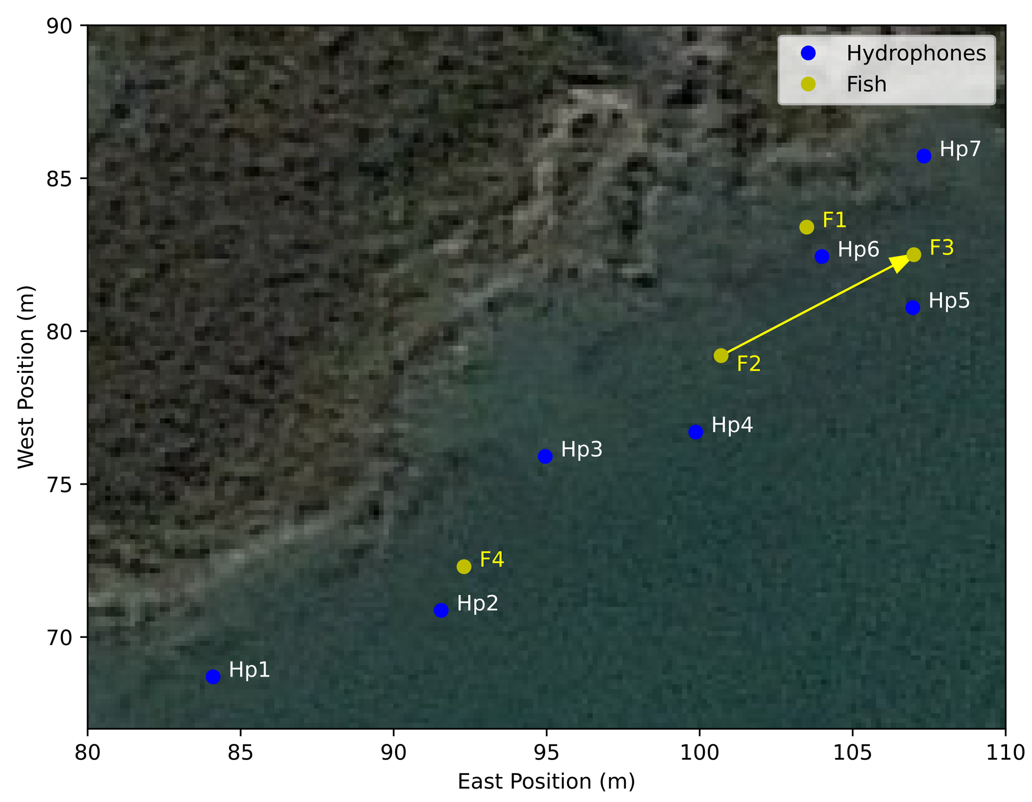

Figure 3: Hydrophone positions with fish detections at Clambank Creek. **F1**–a sea robin detected at 2017-06-01T12:54 (UTC-4); **F2**–a spotted seatrout *Cynoscion nebulosis* detected at 2017-06-01T18:29:21 (UTC-4); **F3**–the same spotted seatrout as F2 detected at 2017-06-01T18:30:21; **F4**–a striped blenny *Chasmodes bosquianus* detected at 2017-06-01T21:06:22. The arrow shows the motion of the spotted seatrout between F2 and F3. (Satellite image obtained from Google Earth.)

Using the time delays between array channels, we determined the locations of many fish in the recordings, including those shown in Fig. 3. We "followed" a spotted seatrout as it voclalized continually while moving between points F2 and F3 in Fig. 3 over 60 s.

Discussion and Conclusion

We have demonstrated that sound-producing fish can be located and tracked using a hydrophone array deployed in a sub-optimal configuration in very shallow water. The measurements of the calibration sound positions with a laser rangefinder had sufficient accuracy to calibrate hydrophone positions acoustically with results that were consistent with independent WAAS-GPS measurements. Using the hydrophone positions we were able to locate and track vocalizing fish in the recordings. In the future we will use this technique to locate groups of fishes producing sound and to determine how these fish move throughout the day.

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