Soundscapes from a Saltwater Marsh Creek Captured by a Hydrophone Array

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Abstract

A seven-hydrophone array was deployed in a shallow saltwater creek at the University of South Carolina Baruch Marine Field Laboratory in the North Inlet-Winyah Bay National Estuarine Research Reserve near Georgetown, South Carolina, USA, and sounds were recorded for 24 h from June 01 through June 02, 2017, to identify and localize soniferous animals in the water and to serve as a proof of concept for future studies. The array was calibrated by producing sounds at known locations and using triangulation to determine the hydrophone positions. Similarly, the calibrated hydrophone positions were used to determine the positions of soniferous animals from the signal delays between the different hydrophones using triangulation. The locations of three fish, including one that was moving as it vocalized, are shown.

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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, a seven-hydrophone array was deployed in a very shallow saltwater creek to learn about the locations of sound producers and their movements.

The study site was Clambank Creek (33°20′2.57”N, 79°11′34.58”W), 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, South Carolina, USA (see Fig. 1). The goal of the study was to determine which soniferous species were present in the creek and how the activity and locations of these sound producers changed throughout the day and to serve as a proof of concept to be used in future studies.

In order to determine the position of a sound source from an hydrophone array, the positions of the hydrophones, the delay between the arrivals of the same signal at

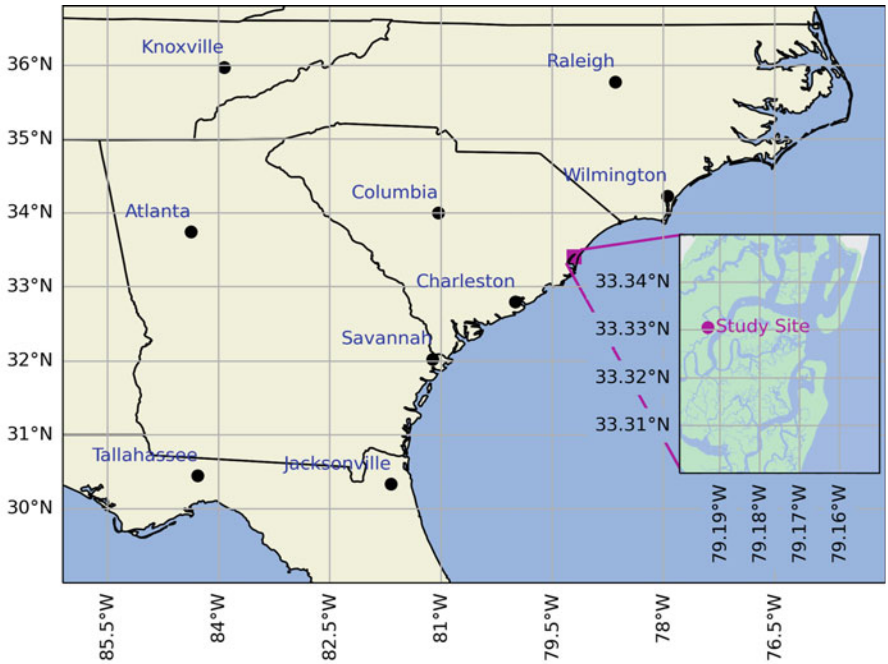

Fig. 1 The study site shown on a map of the southeastern United States

the different hydrophones, and the sound speed are used to determine the source location using triangulation. This chapter describes how each of these parameters were determined to locate and track sound sources in this shallow water environment.

Hydrophones and Recorder

The array consisted of seven HTI-96-Min hydrophones (High Tech, Inc., Long Beach, MS, USA). A 100 m, nine-conductor cable (conductors for voltage supply, ground, and hydrophone 1–7 signals) connected an eight-track simultaneous-sampling digital recorder (Zoom F8, Tokyo) and voltage supply on the shore to a junction box. Each hydrophone was connected to the junction box with a 30 m, three-conductor cable (with conductors for voltage, ground, and signal). The recorder made simultaneous 24-bit recordings from each hydrophone sampled at 44100 Hz and stored them on a SD card in the Broadcast Wave file format.

Reference Positions

Four reference positions (see Fig. 2) were used to accurately locate the position of each hydrophone. At each reference position, a large metal target was positioned so it was visible throughout the site. The location of each reference position was measured using a handheld GPS receiver (Garmin GPSMAP 78sc, Olathe, KS, USA) with Wide Area Augmentation System-enabled Global Positioning System (WAAS-GPS).

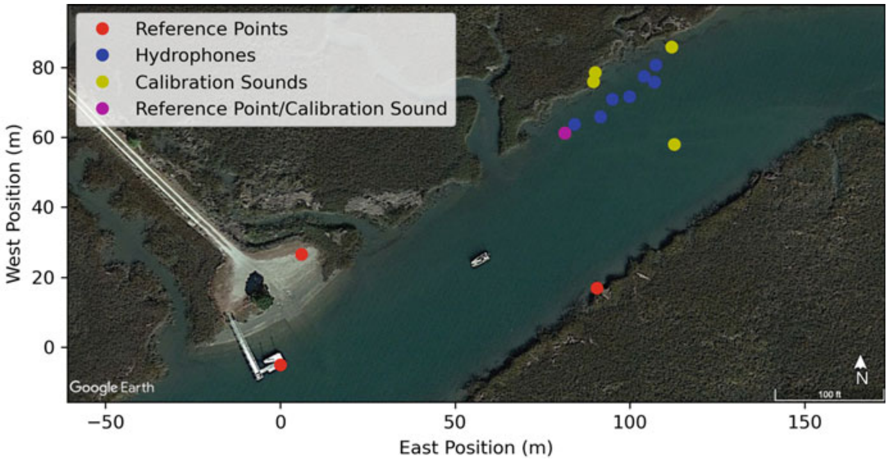

Fig. 2 Positions of the reference markers, hydrophones, and calibration sounds at Clambank Creek. The Clambank water quality monitoring station is located on the pier on the bottom left of the image. (Satellite image obtained from Google Earth)

Array Deployment

The array was deployed on June 01, 2017, in water depths of 1.00–1.70 m by wading into the water and mounting the hydrophones on rods connected to cinder block anchors placed on the creek bed. The water depth and time of day were recorded at each hydrophone site. Hydrophone positions were measured with the GPS receiver for validation of the hydrophone locations to be determined by the calibration procedure (section "Array Calibration"). Figure 2 shows the hydrophone positions at the study site. The array configuration was suboptimal with hydrophone locations influenced by bottom conditions and the ability to secure the hydrophone in place while wading.

Array Calibration

To calibrate the array, impulsive sounds were produced underwater at five positions, determined by triangulation of laser rangefinder (Laser Tech TruePulse 360 °R, Centennial, CO, USA) measurements of the distances to the reference position and also using WAAS-GPS for validation. One of the calibration sounds was produced at the location of reference point 3 (see the reference point/calibration sound point in Fig. 2). The delays of the calibration sounds on the different hydrophone recordings were used to calibrate the array by solving sound propagation equations for the distances from the calibration sounds to each hydrophone and using triangulation to determine the hydrophone positions.

The small pier in Fig. 2 at the second reference point is the location of a National Oceanic and Atmospheric Administration (NOAA) tide and water quality measuring station (station 8662299 Clambank Creek Dock), allowing the determination of the water depth and water quality parameters. The local speed of sound in the water, which was determined with the equation developed by the United Nations Educational, Scientific and Cultural Organization Division of Marine Sciences (the UNESCO equation; Fofonoff and Millard 1983; Wong and Zhu 1995) using water quality measurements taken every 900 s (15 min). Sound speed values for times between the 900-s water quality samples were determined using a third-order cubic spline interpolation.

Sound Recordings and Source Localization

Sounds were recorded for 24 h and identified using knowledge of the fishes in the estuary (Simpson et al. 2015) and by comparing them to recordings of captive fish. The locations of recorded fish were determined by measuring the signal time delays between each hydrophone recording and solving acoustic propagation equations for the source position using the interpolated local speed of sound in the water.

The soundscape recordings contained rich acoustic activity, including sounds produced by Atlantic croaker *Micropogonias undulatus*, bighead searobin *Prionotus*

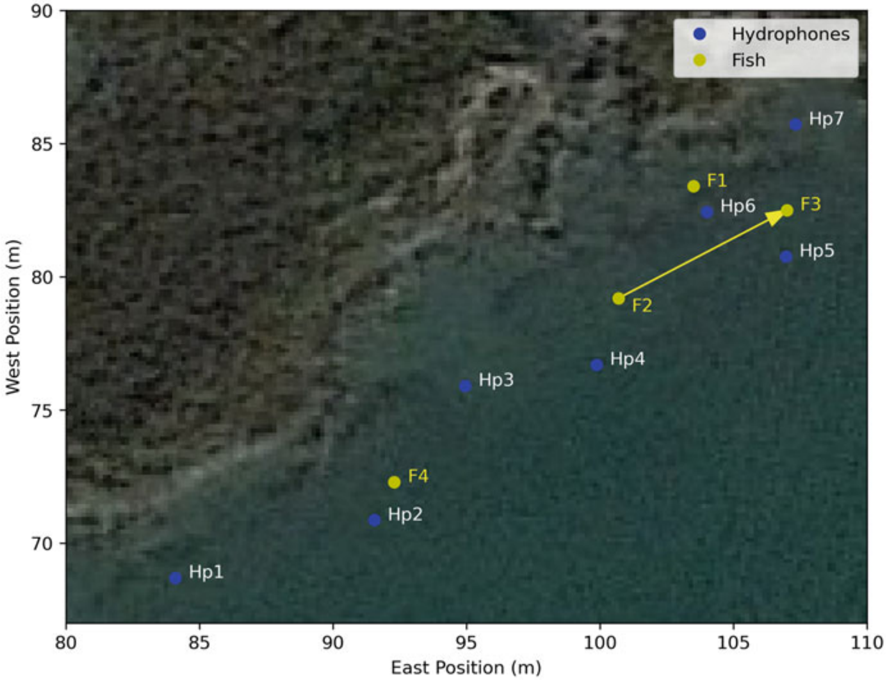

Fig. 3 Hydrophone positions with fish detections at Clambank Creek. **F1**, a sea robin detected at 2017–06-01 T12:54 (UTC-4); **F2**, a spotted seatrout *Cynoscion nebulosus* detected at 2017–06-01 T18:29:21 (UTC-4); **F3**, the same spotted seatrout as F2 detected at 2017–06-01 T18:30:21; **F4**, a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

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). Using the time delays between the same signals in the array channels, the locations of many fish in the recordings were determined. The localized fish sounds shown in Fig. 3 include a bighead searobin at point F1, a spotted seatrout that was "followed" as it vocalized continually for over 60 s as it moved from point F2 to F3, and a striped blenny at point F4.

Discussion and Conclusion

This chapter demonstrates that sound-producing fish can be located and tracked using a hydrophone array deployed in a suboptimal 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. The hydrophone positions and measured time delays of sounds in the recording were used to locate and track vocalizing fish. In the future this technique will be used to locate groups of fishes producing sound and to determine how these fishes move throughout the day.

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References

Fischer FP, Schulz U, Schubert H, Knapp P, Schmöger M (1997) Quantitative assessment of grassland quality: acoustic determination of population sizes of orthopteran indicator species. Ecol Appl 7(3):909–920. https://doi.org/10.1890/1051-0761(1997)007. [0909,QAOGQA]2.0.CO;2

Fofonoff NP, Millard RC (1983) Algorithms for computation of fundamental properties of seawater. UNESCO technical papers in marine science 44. UNESCO division of marine sciences, Paris

Luczkovich JJ, Sprague MW (2022) Soundscape maps of soniferous fishes observed from a mobile glider. Front Mar Sci 9(2296–7745). https://doi.org/10.3389/fmars.2022.779540. https://www.frontiersin.org/article/10.3389/fmars.2022.779540

Parks SE, Miksis-Olds JL, Denes SL (2014) Assessing marine ecosystem acoustic diversity across ocean basins. Eco Inform 21:81–88. https://doi.org/10.1016/j.ecoinf.2013.11.003. https://www.sciencedirect.com/science/article/pii/S1574954113001167, ecological acoustics

Pijanowski BC, Farina A, Gage SH, Dumyahn SL, Krause BL (2011) What is soundscape ecology? an introduction and overview of an emerging new science. Landsc Ecol 26(9):1213–1232. https://doi.org/10.1007/s10980-011-9600-8

Simpson RG, Allen DM, Sherman SA, Edwards KF (2015) Fishes of the north inlet estuary: a guide to their identification and ecology. Special publication, Belle W. Baruch institute, University of South Carolina

Wong GS, Zhu S (1995) Speed of sound in seawater as a function of salinity, temperature, and pressure. J Acoust Soc Am 97(3):1732–1736