A New Technology for Continuous Long-Range Tracking of Fish and Lobster

By Thomas Rossby, Godi Fischer, and Melissa M. Omand

In an article on horizontal diffusion, Henry Stommel (1949) suggested using the recently discovered deep sound or SOFAR channel to track neutrally buoyant floats over hundreds of kilometers. This was an idea ahead of its time, but in 1965 he encouraged Douglas Webb to take a fresh look at the concept. This led in 1969 to the first successful demonstration tracking of a neutrally buoyant float in the deep sound channel for four months. Soon after, in 1973, 20 SOFAR floats were deployed to study mesoscale eddy motion in the Sargasso Sea. A major evolutionary step took place in 1984 with the development of the isopycnal RAFOS float, a glass pipe designed to listen to coded signals from moored sound sources. This approach brought down system cost substantially, and made it easy to conduct Lagrangian studies anywhere in the world (see Rossby, 2007, for a history of float technology). In a further expansion of this technology, Rossby (2016) shows how the Lagrangian method can help visualize flow patterns in the ocean.

With this evolutionary process as background, we proposed development of a "micro-sized" RAFOS receiver that could be attached to fish for tracking their movements over time. The technical challenges were substantial, the primary one being to reduce the power drain to micro-Watt levels so that the battery, and hence package size, would permit its use on a variety of animals such as flounder, cod, and lobster. This capability has now been realized in an archival fish-tag that can listen for and record the arrival times of acoustic signals. A cylindrical housing (see insert in Figure 1), which functions as the hydrophone, encloses a micro printed circuit board bearing a dedicated chip (the "fish-chip") that performs all the standard RAFOS functions of listening and cataloguing the strongest signals at scheduled times, measuring temperature and pressure, and logging all these in up to four memory chips each with 1 Mb capacity (Fischer et al., 2006). With two 1.5 V batteries the tag can, for example, listen a dozen times a day for two years while sampling pressure and temperature every 30 minutes in order to capture vertical movements in the water column. The fish-tag can operate at almost any depth, depending upon the rating of the pressure sensor. A detailed report of the technology will be published elsewhere.

As part of a final validation of the technology, we recently conducted a field test in the Gulf of Mexico. Five fish-tags and two pods (functionally equivalent to a tag, but in a PVC housing to facilitate evaluation of the electronics) were deployed on two surface drifters at about 30 m depth. GPS trackers on the drifters reported their positions every five minutes. After their release, we transmitted acoustic signals from various distances. A standard RAFOS

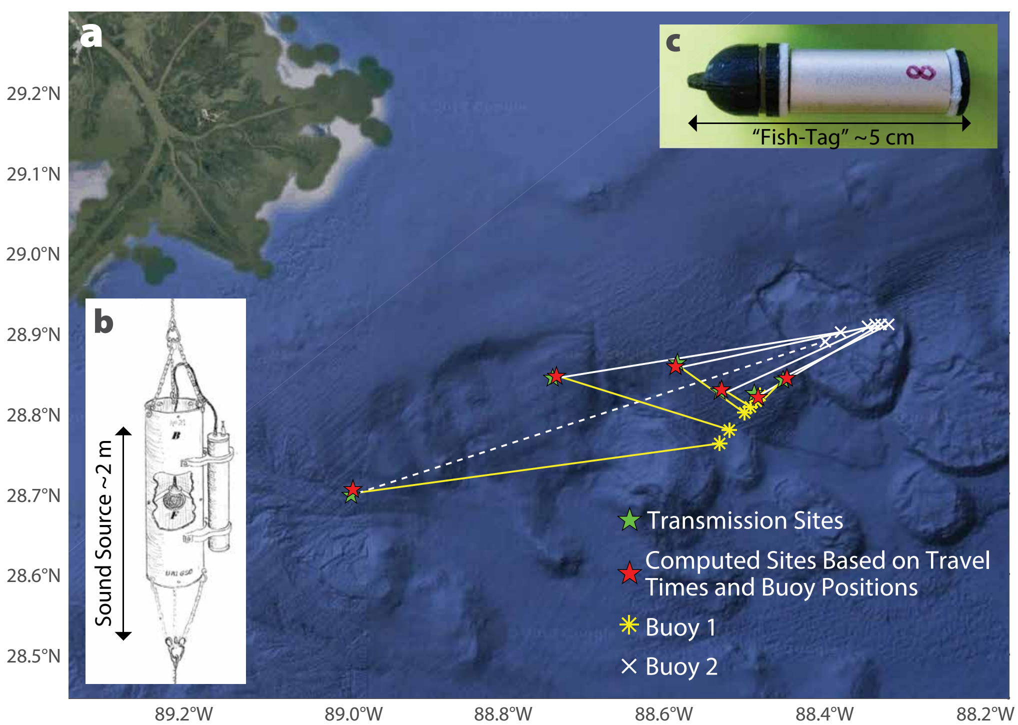

FIGURE 1. Field test of the "fish-tag" in the Gulf of Mexico. The yellow stars and white crosses show the GPS locations of the drifters at the times of transmission from the sound source (green stars). The red stars show the computed positions for each case. The dashed white line indicates that this travel time was reconstructed to take advantage of the corresponding yellow line. The top insert shows the fish-tag prior to applying an external polyurethane coating. The left insert shows the standard sound source, an open pipe driven by a ceramic monopole in its center (*F*). The electronics module mounted on the side of the resonator pipe can operate the source more than four times a day for two years.

sound source (see insert in Figure 1) was hung over the side at 24 m depth and manually activated to transmit once per minute during the first five minutes of the hour when the tags and pods were listening. The source level is 180 dB re 1 µPa at 1 m. The signal consists of a 32-second-long frequency sweep between 260.5 Hz and 263.5 Hz (known as a chirp). The linear chirp has the advantage of being Doppler insensitive. In fact, by chirping in opposite directions, the up-down sequence can be used to remove Doppler effects on tracking accuracy on the one hand, and get an estimate of speed on the other. Normally, a warm surface layer is a terrible place for a long-range transmission test because sound is refracted away from the surface (known by submariners as the "afternoon effect"), but thanks to a thin layer of freshwater from the Mississippi River, a shallow sound channel at the surface enabled us to hear signals from as far away as 60 km. In a typical application, the fish-tags would listen to stationary sound sources, but here, as an illustration, we show how the acoustic arrival times could be used to track the ship. Knowing where the tags were at signal reception times (shown as yellow asterisks and white crosses in the figure), we solve for the location of the transmitter. Red stars are the predicted locations and green stars show the ship's actual position at the time. The accuracy of this prediction ranged from 70 m to 560 m. The navigational accuracy depends critically upon clock accuracy in the tags, in this case made easy by getting arrival times at zero range on deck. Using standard RAFOS clock error recovery techniques, clock errors can be kept to a few seconds on yearlong missions.

The fish-chip technology is in the process of being adapted to a next generation RAFOS float and other classes of underwater vehicles. Plans are also being laid to study the movement of lobster in Rhode Island Sound in summer/fall 2018. Development of the fish-tag was funded by grants from the National Science Foundation.

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