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[Management Brief]

Anchoring Submersible Ultrasonic Receivers in River Channels with Stable Substrate

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Abstract.—We developed an anchoring system for submersible ultrasonic receivers (SURs) that we placed on the bottom of the riverine reaches of three main-stem reservoirs in the upper Tennessee River. Each anchor consisted of a steel tube (8.9 × 35.6 cm) welded vertically to a round plate of steel (5.1 × 40.6 cm). All seven SURs and their 57-kg anchors were successfully deployed and retrieved three times over 547 d by a dive team employing surface air-breathing equipment and a davit-equipped boat. All of the anchors and their SURs remained stationary over two consecutive winters on the hard-bottom, thalweg sites where they were deployed. The SUR and its anchor at the most downriver site experienced flows that exceeded 2,100 m^3/s and mean water column velocities of about 0.9 m/s.

The use of ultrasonic transmitters and submersible ultrasonic receivers (e.g., VEMCO Model VR2, Halifax, Nova Scotia; Sonotronics Model SUR-1, Tucson, Arizona) to passively monitor fish movements is increasing worldwide as this technology improves. Submersible ultrasonic receivers (SURs) have been used frequently in estuarine and marine environments (e.g., Starr et al. 2000; Lacroix et al. 2004; Clements et al. 2005; Szedlmayer and Schroepfer 2005) and to a lesser extent in lotic environments (e.g., Curry et al. 2002). A problem faced by researchers employing submersible receiver technology in large rivers is how to deploy the receivers to simultaneously achieve good reception of transmitted signals and high receiver retrieval rates. Attaching receivers beneath buoys (which can be lost due to collisions with barges or ice) or anchoring receivers on shifting riverbeds may have maximized receiver performance in several studies but resulted in low SUR retrieval rates (Comeau et al. 2002; Clements et al. 2005). Recently, researchers in the upper Mississippi River have anchored SURs to the river's bottom using metal stands weighted with cement blocks (D. Herzog; Missouri Department of Conservation; personal communication); although those SURs are usually retrieved successfully, the stands (and their SURs) are occasionally lost. Mounting SURs on bridge piers reduces the risk of losing them, but receiver performance can be severely compromised (Casto-Yerty and Bettoli 2009). Additionally, SURs mounted to bridge piers and water control structures on the lower Mississippi River have been lost or damaged during flood events (H. Schramm, U.S. Geological Survey, personal communication). McMichael et al. (2010) surmounted the challenges facing salmon *Oncorhynchus* spp. researchers deploying SURs in the Columbia River by developing a system comprised of a 34–68-kg mooring anchor, acoustic release mechanism, and positively buoyant SUR assembly.

In a pilot study, we tracked paddlefish *Polyodon spathula* in a main-stem reservoir on the lower Tennessee River in which our system of anchoring SURs using concrete-filled washtubs did not perform flawlessly; one SUR (out of six deployed) was permanently lost, one was lost for more than four months, and several were tipped on their sides by shifting bed loads or high velocities. We subsequently developed a simple SUR anchor and deployment-and-retrieval process that we used successfully in a regulated river over an extended period to track lake sturgeon *Acipenser fulvescens*.

Methods

SUR anchors.—The SUR anchors were constructed of either a single round plate of steel (5.1-cm thick with a diameter of 40.6 cm) or two round plates (each 2.5-cm thick) welded together with an upright steel tube

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FIGURE 1.—Steel anchor and SUR stand used to deploy SURs in the upper Tennessee River. A Sonotronics Model SUR-1 and steel locking pin are also pictured. The top of the upright tube was painted a contrasting color (white or orange) to aid the diver in seeing the anchor.

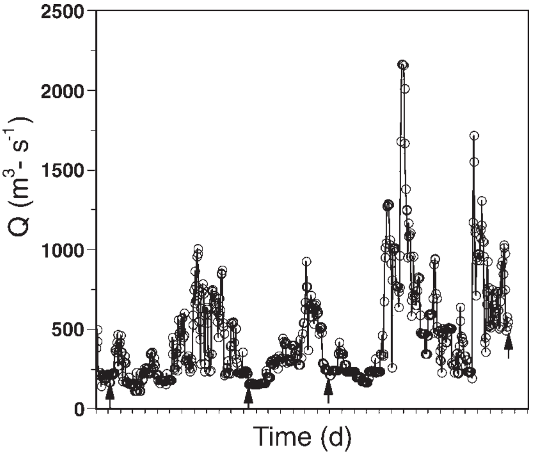

FIGURE 2.—Daily average discharge (Q) through Watts Bar Dam on the Tennessee River between September 1, 2007, and June 30, 2009. Vertical arrows indicate the dates when SURs and anchors were deployed and retrieved, namely, September 26–27, 2007, April 28–29, 2008, September 22–23, 2008, and June 29–30, 2009.

(35.6 cm high; 8.9 cm outside diameter) to hold the SUR (Sonotronics Model SUR-1) upright with the omnidirectional hydrophone exposed (Figure 1). Each SUR had a diameter of 6 cm and was 40.4 cm in total length. The cost per anchor was approximately US$380. Each anchor weighed 57 kg and had a small cross-sectional area, which we hoped would reduce the likelihood of displacement or tipping due to high velocities or collisions with debris. The SUR was held in place by a stainless steel pin (0.5 cm × 14 cm) that passed through holes in the bottom of the vertical tube. Three metal loops welded along the circumference of the steel plates provided attachment points for the cable used to lower and raise the anchor. One end of a 16-m-long tether cable (3.2-mm-diameter clear-vinyl-coated cable) was attached to each SUR anchor and the other (downstream) end was attached to a 19-kg cinder block. These light-colored cables contrasted with the dark substrate at each site and made it easier for the diver to locate each SUR (see below).

SUR deployment.—All SUR deployments (and retrievals) were made on days of low flow (Figure 2). All SURs were deployed by a three-person crew (i.e., a diver, a tender-standby diver, and a surface helper) working out of a 6.4-m dive boat equipped with an umbilical vessel to diver intercom (Ocean Technology Systems, Aquacom MK2-DCI, Santa Ana, California) and surface-supplied air system. All dive operations were conducted within the U.S. Navy no-decompression limits. The tender and surface helper served as guides for the diver during SUR deployment and operated a 225-kg davit and a manual, 454-kg capacity winch that was used to lower and raise the SUR anchor. Deployment sites were preselected by locating narrow river reaches to maximize the ability of the SUR to detect the lateral passage of tagged fish. Some of our SURs were placed in the vicinity of U.S. Coast Guard navigation buoys, which served as useful landmarks, but they were not attached to the buoys or their anchors. When a potential site was identified, the area was traversed with a 16-channel Wide Area Augmentation System Global Positioning System–enabled side-scanning sonar (Humminbird Model 987c SI) to analyze bottom characteristics and detect underwater obstructions that would potentially interfere with SUR operation and maintenance. After selecting the appropriate location, the boat was anchored over the selected site while the SUR anchor was lowered with the davit and winch. The winch cable was attached to a single loop on the anchor, which tilted upwards slightly as it was lowered. We endeavored to record an accurate GPS coordinate when the boat was directly above the SUR. The diver then deployed to inspect the SUR anchor to ensure it was properly positioned (i.e., with the SUR and its hydrophone pointing straight up). Then the diver, directed by the surface crew, stretched the tether cable directly downstream of the SUR to aid in future recovery operations. Before returning to the boat, the diver disconnected the winch cable from the SUR anchor.

Seven SURs were deployed on September 26–27, 2007, in the upper Tennessee River and two of its tributaries (Figure 3) to monitor lake sturgeon movements and dam passage. All SURs were deployed in the

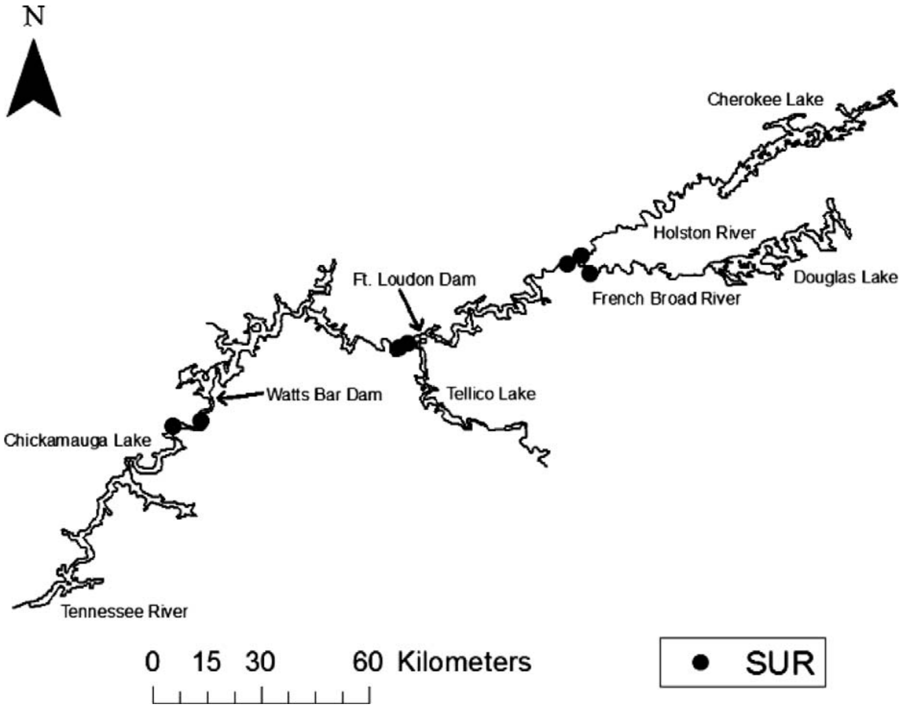

FIGURE 3.—Map of the upper Tennessee River reservoirs where seven SURs were deployed and retrieved three times between September 2007 and June 2009. The Tennessee River flows to the southwest.

main channel in their respective reaches. The SURs were anchored at depths ranging from less than 6 m in the Holston River to about 17 m below Fort Loudon Dam. We did not measure water velocity at the bed at any SUR site during our study. Instead, we measured cross-sectional areas at the two uppermost sites (in the French Broad and Holston rivers) and the lowermost site (below Watts Bar Dam) on May 11, 2010. We then estimated the average water column velocity at those sites (after adjusting for differences in river stage) on the dates of maximum discharge during our study.

SUR recovery.—The SURs were recovered by carefully positioning and securing the boat with anchors over the previously recorded waypoint. Ideally, the distance readout on the sonar–GPS unit from the boat to the waypoint was kept at less than 3 m before the diver began searching for the SUR. The diver conducted a perpendicular-to-flow pattern search downstream of the waypoint at the direction of the surface crew until the tether cable or SUR was located. Once the anchored SUR was located, the diver and surface crew worked together to position the boat directly over the SUR by adjusting the boat's anchor line, and then the surface crew used a weighted clevis to send the winch cable down the diver's umbilical cord. The winch cable was then attached to the SUR anchor; the diver and crew checked to be sure that the diver's umbilical cord was clear of the winch cable before retrieval began. If water conditions prevented diving, the SURs could theoretically have been retrieved by dragging for the cable; however, we never had to perform this particular task.

Results and Discussion

The SUR in the French Broad River arm of upper Fort Loudoun Lake (the tailwater of Douglas Dam) experienced an average daily flow of 98 m^3/s and a maximum flow of 483 m^3/s during its 547-d deployment. In the Holston River arm of Fort Loudon Lake (the tailwater of Cherokee Dam), the average daily and maximum flows were 59 and 362 m^3/s, respectively. The SUR positioned downstream of the confluence of those tributaries was in the lacustrine zone of Fort Loudon Lake and experienced the combination of those inflows. The average daily and maximum flows in the Tennessee River below Fort Loudon Dam were 306 and 1,468 m^3/s, respectively. The two lowermost SURs in the Tennessee River below Watts Bar Dam experienced average daily and maximum flows of 454 and 2,167 m^3/s, respectively, over the 547-d study.

All SURs and anchors were successfully relocated, retrieved, and downloaded on April 28–29, 2008, September 22–23, 2008, and June 29–30, 2009; thus, we performed 21 deployments and 21 retrievals and lost no SURs or data. We did not measure the bed velocities acting on each SUR anchor; however, the velocity required to move our anchors (i.e., the overturning threshold velocity) was estimated to be 3.6 m/s (V. Neary, Oak Ridge National Laboratory, personal communication), nearly an order of magnitude greater than the velocities measured near the bed in large rivers like the Mississippi River (McQuivey 1973). We estimated that the average water column velocities at the sites in the French Broad River, the Holston River, and the Tennessee River below Watts Bar Dam on the dates of maximum discharge were 0.6, 0.7 and 0.9 m/s, respectively.

On one date, the bases of two SUR anchors were slightly silted over and fouled with some aquatic vegetation when retrieved, but each SUR (and its omnidirectional hydrophone) always remained above the substrate. Although we did not conduct field trials of their ability to detect the passage of tagged fish, the seven SURs logged thousands of detections of the 37 tagged lake sturgeon over their approximately 547-d deployments. In future deployments, it would be advisable to test the efficacy of our bottom-mounted SURs by pulling submersed pinger tags at known distances from the SURs (e.g., Shroyer and Logsdon 2009).

The vertical tube on our anchor was designed to accommodate the Sonotronics SUR-1 we used in our study as well as the larger-diameter Vemco VR2 SUR. The Sonotronics SUR-1 did not fit snugly within the tube and there is a possibility that acoustical signals were generated if (or whenever) the SUR contacted the tube. In future deployments we will wrap foam around the SUR-1 to hold it firmly in place within the tube to eliminate the possibility of acoustical interference.

None of our SURs were placed in the sediment deposition zones of their respective reservoirs. All of our SUR anchors were placed on firm, rocky substrate in the thalweg of the three rivers (Holston, French Broad, and Tennessee), where the likelihood of bed-shifting was low. Although our simple and inexpensive SUR anchor system performed flawlessly in our riverine environments, it would be ill-advised for systems such as the Mississippi River, in which shifting, sandy substrates would probably bury the SUR and its anchor. The problem of retrieving SURs that are deployed in the upper Mississippi River, where shifting bed loads can quickly bury SUR anchor stands, is still being addressed (R. C. Brooks and coworkers, Fisheries and Illinois Aquaculture Center, unpublished report). The engineering and development work performed by McMichael et al. (2010) to design a safe, efficient, and cost-effective system to deploy and retrieve arrays of SURs in the Columbia River, where many of the same challenges exist, will undoubtedly aid researchers in the Mississippi River and elsewhere.

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David Herzog and Joe Hightower provided helpful comments on an earlier draft of this paper. Will Collier prepared the map of our study sites and supplied information on the number of tag detections by each SUR. Eric Ganus was the diver on all SUR deployments and retrievals. The use of trade, product, industry, or firm names or products is for information purposes only and does not constitute an endorsement by the U.S. Government.

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