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Stephen L. Webb
Mississippi State University, slwebb@noble.org

Joshua A. Gaskamp
Samuel Roberts Noble Foundation

Kenneth L. Gee
Samuel Roberts Noble Foundation

Stephen Demarais
Mississippi State University, steve.demarais@msstate.edu

Andrew R. Little
Mississippi State University, alittle6@unl.edu

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Design of an Underwater Telemetry Antenna for Locating and Retrieving Submerged Radiocollars

Stephen L. Webb,[1] Joshua A. Gaskamp,[2] Kenneth L. Gee,[2] Stephen Demarais,[1] and Andrew R. Little[1]

1 Department of Wildlife, Fisheries and Aquaculture, Mississippi State University, Box 9690, Mississippi State, MS 39762

2 Samuel Roberts Noble Foundation, 2510 Sam Noble Parkway, Ardmore, OK 73401

Corresponding author — S. L. Webb, *email* stephenwebb@hotmail.com ; *present address* Hayden-Wing Associates, 2308 S 8th Street, Laramie, WY 82070, USA

Abstract

Radiocollars represent a significant investment of financial resources, particularly global positioning system (GPS) collars, and loss of data imposes analytical limitations from reduced sample sizes. Radiocollars on large, terrestrial mammals are seldom lost in the water. However, several instances in Oklahoma, USA necessitated a reliable and cost-effective technique for retrieving GPS collars from underwater to salvage the financial investment and data. We designed an underwater telemetry antenna to find and retrieve collars in ≤ 3 m of water. We describe field simulations under varying environmental and water conditions, and provide a list of materials along with instructions and considerations for building and using an underwater telemetry antenna. We successfully used our underwater antenna to locate and retrieve our submerged collar that was disposed of in a pond after illegal harvest; we also located and retrieved all collars used for field simulation (n = 11). On average, search time for collars was 30 min. The design of our underwater antenna was inexpensive (US$30), easy to build, and effective at locating submerged collars in 0.6–3.0 m of water, with varying water turbidity and substrates. Although our underwater telemetry antenna was designed to meet our needs, it could be modified for more specific or alternative circumstances.

Keywords: antenna, GPS, radiocollars, telemetry, underwater, VHF.

Radiocollars on large, terrestrial mammals are seldom lost in the water. However, we recovered global positioning system (GPS) collars from underwater in 2 of 64 (3%) collar deployments over 8 yr in southern Oklahoma, USA. Previous studies have noted that animals may succumb to illness while seeking water, or may drown (Harper 1965, Hoskinson and Mech 1976, Peris and Morales 2004), resulting in loss of the animal and collar. Other instances that may require retrieving collars from the water include 1) slipped collar while the animal drinks, 2) released collar while in or near water, or 3) disposed collar after illegal harvest to eliminate evidence. Although loss of any radiocollar represents a financial burden, the loss of GPS collars is particularly problematic due to their cost and loss of data when data are stored on-board.

Researchers have designed and used underwater antennas for recovering duckling and amphibian radiocollars from ponds (Kenow et al. 1992, Fellers and Kleeman 2003), but in most instances radiocollars were in shallow water. To our knowledge, an underwater antenna has not been designed for water >2 m in depth with the ability to be completely waterproof and that also has the capability to retrieve collars >1 kg in weight.

The disposal of a GPS collar into a pond after illegal harvest of a white-tailed deer (*Odocoileus virginianus*) prompted us to develop an underwater telemetry antenna capable of finding and retrieving the submerged collar. Triangulation of the very-high-frequency (VHF) signal indicated the collar was within a pond with 1.1-ha surface area and a maximum depth exceeding 3.6 m. The surface area and depth precluded recovery with traditional methods (e.g., wading, rake drag, or visual detection), which necessitated the development of an underwater telemetry antenna. In this paper, we define materials required for building, assembling, and using the underwater antenna. We also provide recommendations for further refining the under- water antenna based on field simulations of finding submerged collars.

STUDY AREA

We used our underwater antenna to find submerged collars at one pond near Marietta, Oklahoma (Carter County) and 4 ponds near Ardmore, Oklahoma (Carter County). The ponds were located in southern Oklahoma, which was part of the Cross Timbers and Prairies ecoregion and was characterized by mixtures of wooded uplands and naturally occurring openings (Gee et al. 1994). Ponds ranged in size from 0.2 surface ha to 1.1 surface ha, with varying water depths and bottom substrates (Table 1).

Table 1. Time (min) required to locate submerged global positioning system (GPS) collars with an underwater telemetry antenna at varying water depths, weather conditions, water properties, and bottom substrates. Ponds were located in southern Oklahoma (1 in Marietta and 4 in Ardmore, Carter County, Oklahoma, USA), which is part of the Cross Timbers and Prairies ecoregion.

Environmental conditions[a]	*Water*	*Depth (m)*	*Substrate*	*Min*
Clear, 18.08, 12 km/hr[b]	Muddy turbidity, no vegetation	2.0	Mud, silt	45
Clear, 33.98, 13 km/hr	Phytoplankton turbidity, no vegetation	0.8	Soft mud, humus	20
Mostly clear, 28.98, 8 km/hr	Phytoplankton turbidity, no vegetation	1.7	Hard clay[c]	36
Mostly clear, 30.08, 8 km/hr[d]	Phytoplankton turbidity, no vegetation	1.4	Soft mud	29
Mostly clear, 30.68, 8 km/hr[d]	Phytoplankton turbidity, no vegetation	2.1	Limbs, sticks, rocks[e]	28
Mostly clear, 30.68, 8 km/hr	Phytoplankton turbidity, no vegetation	0.7	Soft mud, some sticks	15
Mostly clear, 31.78, 8 km/hr[f]	Phytoplankton turbidity, no vegetation	1.5	Soft mud	30
Mostly clear, 31.78, 8 km/hr	Phytoplankton turbidity, no vegetation	1.2	Soft mud	22
Mostly clear, 33.98, 8 km/hr	Clear, coontail[g]	3.0[h]	Soft mud, some rock	91
Mostly clear, 35.08, 8 km/hr	Clear, dense coontail[g]	1.5	Humus, coontail	18
Mostly clear, 35.08, 8 km/hr	Sediment turbidity	0.8	Soft mud[i]	6
Mostly clear, 35.08, 8 km/hr[j]	Sediment turbidity	0.6	Sand	15

a. Environmental conditions refer to sky conditions, temp (°C), and wind speed (km/hr).
b. Submerged GPS collar, containing data, which was disposed of due to illegal hunting.
c. Easy to locate collar on substrate, but harder to hook because hard clay was not forgiving.
d. Used fish marker buoy to mark collar after finding collar.
e. Difficult to feel collar because of debris on bottom (limbs, sticks, rocks).
f. Nearby power lines caused static interference with receiver.
g. Coontail (*Ceratophyllum demersum*).
h. Antenna became difficult to maneuver without a counterbalance (e.g., wt or water-filled polyvinyl chloride pipe) at this depth due to flexibility of antenna.
i. Collar was easy to locate on substrate in small pond (0.2 surface ha).
j. Some signal bounce occurred because pond was enclosed by a dense stand of tall trees.

METHODS

Underwater Antenna Construction

Materials (part nos. referenced in Fig. 1) required to construct the waterproof, underwater telemetry antenna are: schedule-40 polyvinyl chloride (PVC) pipe (length = 304.8 cm; inside diam = 2.54 cm; outside diam = 3.33 cm; quantity = 1 [2 for extension; optional]; Part A); PVC cap (inside diam = 3.33 cm; quantity = 1; Part B); male adapter Mipt × Slip PVC fitting schedule-40 (quantity = 1; optional); female adapter Slip × Fipt PVC fitting schedule-40 (quantity = 1; optional); PVC primer and cement; RG-58 coaxial cable assembly (length = 609.6 cm; quantity = 1; Part C); BNC-to-PL-259

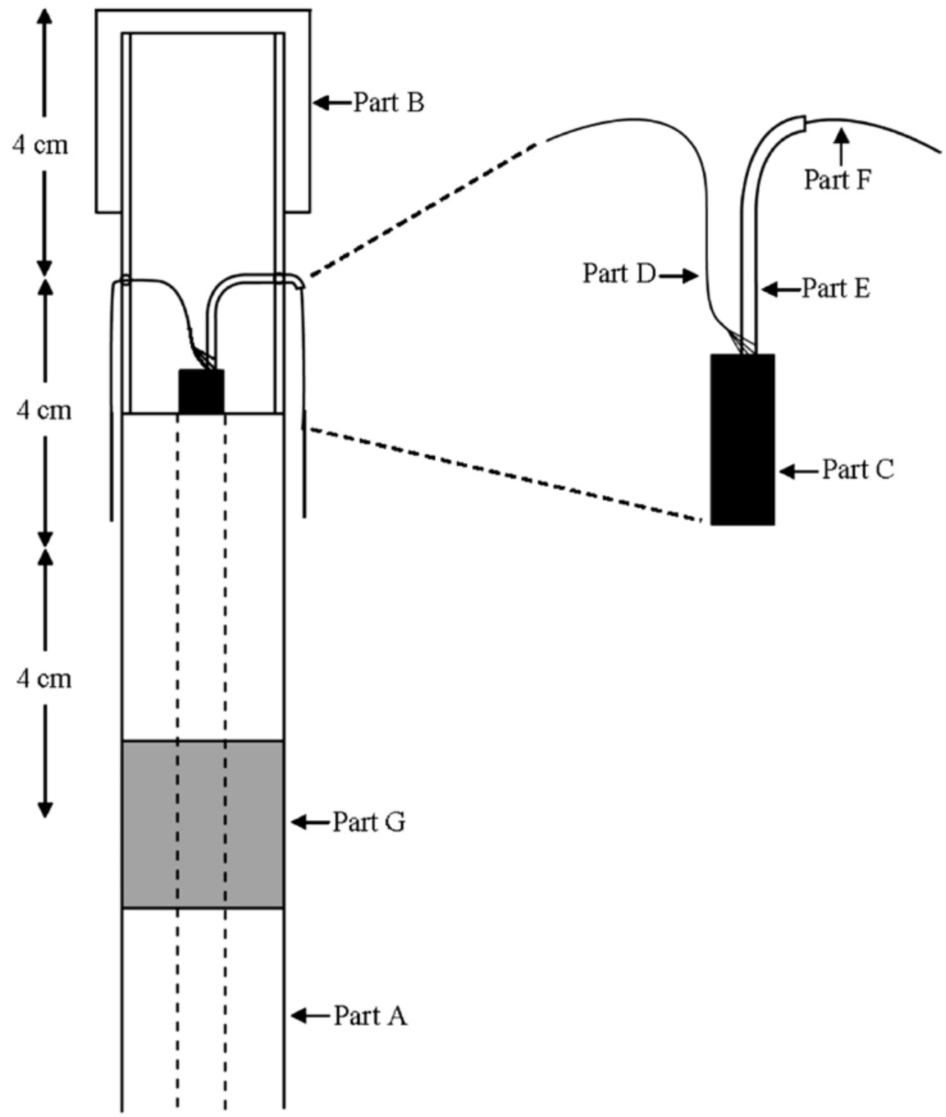

Figure 1. Underwater telemetry antenna schematic for locating submerged radiocollars. Items needed to complete antenna assembly were: schedule-40 polyvinyl chloride (PVC) pipe (Part A), PVC cap (Part B), and RG-58 coaxial cable (Part C). The mesh wires located inside of the coaxial cable were twisted into a single 7.5-cm wire conductor (Part D).We removed 3 cm of insulation (Part E) to expose the single center conductor (Part F). To reduce buoyancy, an optional plug (approx. 2.5 cm) made of room temperature vulcanizing (RTV) silicone sealant can be inserted approximately 12 cm from the antenna end (Part G). Figure developed by B. Washington, Mississippi State University.

adapter (quantity = 1; RadioShack, Fort Worth, TX [http://www.radioshack.com], model 278-120); room temperature vulcanizing (RTV) silicone sealant; electrical tape; and plastic J-hook pipe hanger (note: metal pipe hangers may cause interference; quantity = 1).

To prepare the coaxial cable for assembly, we cut the connector off one end of the RG-58 coaxial cable and removed approximately 7.5 cm of the outer insulation (Fig. 1). Next, we separated the exposed outer-mesh wire conductors from the center conductor insulation and twisted them together to form one wire conductor (Fig. 1, Part D). Last, we removed approximately 3 cm of the inner insulation from the center conductor (Fig. 1, Part E) to expose the center conductor (Fig. 1, Part F), creating 2 separate wires. We prepared the PVC pipe by cutting the bell end (i.e., flared end) off of the PVC pipe and drilled 2 holes (diam = 0.6 cm) approximately 4 cm from the end of the PVC pipe and 1808 apart (Fig. 1). This end, hereafter referred to as the antenna end, was left open for easier installation of the coaxial cable. We then glued the female adapter Slip × Fipt PVC fitting onto the opposite end of the pipe (hereafter, control end). To allow for extension of the antenna, we glued the male adapter Mipt × Slip PVC fitting onto a second schedule-40 PVC pipe. A second PVC pipe and female and male adapters are only necessary if water depth is >3 m.

We put the coaxial cable and PVC pipe together by feeding the coaxial cable, stripped end first, through the control end of the PVC pipe. Next, we inserted the 2 exposed wires through the 2 drilled holes of the antenna end leading to the outside of the pipe (Fig. 1). We directed approximately 4 cm of the wires toward the control end of the pipe (Fig. 1). We positioned the wires flush against the PVC pipe and secured them with electrical tape to hold them in place, leaving ≥1 cm of the wires exposed (Fig. 1). We coated all exposed wire–insulation interfaces and all drilled holes with RTV silicone rubber adhesive sealant to prevent water intrusion. To complete the antenna assembly, we allowed silicone adhesive to dry before gluing the PVC cap to the antenna end (Fig. 1). We also affixed a J-hook pipe hanger with electrical tape to the antenna end to facilitate retrieval of the submerged collar. While mounting the pipe hanger, we avoided taping over the exposed wires. We attached the BNC-to-PL-259 adapter to the coaxial cable on the control end of the antenna that we finally attached to our telemetry receiver.

Retrieval of Collars

We used a fisherman's innertube and signal strength of the VHF beacon to locate and direct movements to a submerged collar. We lightly bounced the antenna along the bottom of the pond while moving the innertube with slow foot-strokes toward the strongest signal of the collar. As the signal strength became too strong to differentiate direction, we dialed down the frequency (e.g., from 153.170 MHz to 153.164 MHz), which reduced the signal strength and allowed additional directional navigation. When we were unable to detect the specific direction to the collar, we moved the underwater antenna along the pond floor to feel for the collar. Once the collar was felt, we hooked it with the pipe hanger to bring it to the surface. When searching in relatively deep water, we used a fish marker buoy to mark the collar upon initial location, which allowed us to discontinue telemetry and start retrieval with the attached pipe hanger.

We conducted field simulations to find randomly submerged GPS collars (n = 11) using the same observer over time to determine whether there was a learning curve in finding submerged collars. A second participant randomly threw collars into the water at locations unknown to the observer; therefore, collars occurred at varying depths, which may have influenced search time. For retrieval of the lost collar and subsequent field simulations, we recorded date, pond location, collar frequency, start and end times, temperature, weather conditions, water conditions, collar depth, and bottom substrate. We used multiple linear regression models to determine whether search time was related to water depth (m) and order of retrieval (SAS$_{1}$ 9.2; SAS Institute Inc., Cary, NC); order of retrieval was used to assess whether there was a learning curve for finding collars underwater. We used normal probability plots (i.e., residual plots) to ascertain whether assumptions of regression models were satisfied; all assumptions were satisfied.

Results

On average, total search and recovery time was 29.6 min (±22.0 SD; range = 6–91, n = 12; Table 1). After removing one outlier, search and recovery time was related to water depth and order of retrieval ($R_{2\,=}$ 0.806, $F_{2,8\,=}$ 16.66, P = 0.001, n = 11). Water depth was positively correlated with search time ($\beta_{depth\,=}$ 12.01 ± 3.75) whereas order of retrieval was negatively correlated with search time ($\beta_{order\,=}$ –1.53 ± 0.59). Bottom substrate (e.g., sticks, limbs, and rocks) influenced the ability to locate the exact position of the collar. On substrates such as clay, collars were easy to locate but difficult to hook because such surfaces made it difficult for the hook on the antenna to maneuver into position for retrieval. The underwater antenna became difficult to maneuver in deep water (approx. 3 m) due to buoyancy, which may require further modification to the antenna design (see below).

Discussion

The design of our underwater telemetry antenna was inexpensive, easy to build, and effective at locating submerged collars in 0.6–3.0 m of water. Loss of GPS collars is a substantial monetary loss (approx. US$3,000), so development of an underwater telemetry antenna was essential for locating and retrieving submerged collars. The increased use of GPS collars for wildlife research will lead to additional instances for locating collars underwater, particularly in coastal and lowland areas prone to flooding and arid regions where animals spend more time near free-standing water. Our underwater antenna was designed to meet our needs, but could be modified for more specific or alternative circumstances.

Additional modifications could be made to the underwater antenna to help with searching or retrieval. Use of the pipe hanger for collar retrieval would be optional depending on the depth or weight of the collar. Other collar retrieval devices could be used as long as they did not interfere with the collar signal back to the receiver. We struggled with antenna maneuverability (i.e., floating to the surface) because it was hollow. To overcome buoyancy, we recommend making a 2.54-cm plug inside of the antenna using RTV silicone sealant approximately 12 cm from the antenna end (Fig. 1, Part G). Drilling holes (n = 4–6; diam = 0.6 cm) above the silicone plug will allow water to enter the pipe, which should reduce buoyancy.

There are other considerations for finding submerged collars with motion switches. When homing narrows the search to within a few meters of the collar, using the antenna to feel for the collar may be required. If the collar is still in mortality mode (e.g., more frequent pulse frequency), bumping the collar with the antenna may change pulse frequency and help locate the exact location of the collar. When collars were equipped with motion-switches, bumping the collar resulted in the emission of erratic pulses. If the pond substrate has varying terrain or structure (e.g., sticks, limbs, or rocks) it may be difficult to determine when the collar has been found unless the collar provides some signal that it is being moved. However, we noticed that collars are highly variable in their sensitivity to being moved. Some collars emit activity pulses after being moved only a few centimeters, whereas others must be moved several meters (K. L. Gee and J. A. Gaskamp, personal observations).

Other methods and considerations may be considered when searching for submerged collars without motion switches. Researchers should retrieve collars as soon as the collar is detected underwater. The collar that was disposed of after illegal hunting activity remained functional (i.e., emitting a VHF mortality signal) while submerged for approximately 82 days. However, a seal on the collar may have become faulty over time, allowing water to enter the collar after the collar was disturbed with the underwater antenna. Water entering the collar may result in loss of data; however, we were able to retrieve all data collected prior to the collar being submerged once the collar was air-dried. During submersion, the collar was unable to successfully record fixes.

Management Implications

Users of radiocollar technology, particularly GPS collars, require techniques to locate missing collars due to expenses associated with each collar and the potential loss of data. Our underwater telemetry antenna was an inexpensive (US $30) and effective method for recovering GPS collars from underwater and under varying environmental conditions, pond surface areas, water depths, and bottom substrates. Having an underwater antenna available when a collar is determined to be in the water will aid in quick recovery of the collar before malfunctions can occur.

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