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[Article]

The Use of Two New Portable 12-mm PIT Tag Detectors to Track Small Fish in Shallow Streams

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Abstract.—This paper describes two prototypes of portable detectors based on radio frequency identification modules and antennas commercially available in Europe and North America for reading small (2.1-mm × 11.5-mm) passive integrated transponder tags. Maximum tag detection distances ranged from 17 to 36 cm, depending on the system and orientation of the tag to the antenna. The efficiency of the detectors was field-tested with both wild juvenile brown trout *Salmo trutta* and adult slimy sculpin *Cottus cognatus* that had been marked by injection of a tag into the peritoneal cavity. By probing the water with the antenna, we were able to detect, on average, 69% of age-1 trout (fork length, 148 ± 26 mm [mean ± SD]), 82% of age-0 trout (fork length, 72 ± 8 mm), and 82% of adult sculpin (total length, 74 ± 9 mm). We did not conduct a formal study to compare the performances of the two prototypes or to determine how habitat characteristics may alter their efficiency.

Passive integrated transponder (PIT) technology has been developed as a technique for individually tagging fish (Prentice and Park 1984; Prentice et al. 1990a). Its use in ichthyological research has increased rapidly in the past two decades, largely in response to technological improvements (review in Lucas and Baras 2000). Automatic PIT interrogation systems have become valuable tools for answering fisheries research and management questions related to the migration and survival of fish passing through fishway orifices (Prentice et al. 1990b; Castro-Santos et al. 1996; Downing et al. 2001) or streamwide antennae (Morhardt et al. 2000; Barbin Zydlewski et al. 2001). Moreover, systems that continuously detect individual fish have proven useful in behavior studies, including those concerned with the fitness-related consequences of activity patterns and habitat selection (e.g., Brännäs et al. 1994; Metcalfe et al. 1999; Martin-Smith and Armstrong 2002; Roussel et al. 2004). Armstrong et al. (1996) were the first to develop a flat-bed antenna design (i.e., a plate antenna laid flat on the stream bottom) that has been used by field biologists to study the habitat use and movement of fish in shallow streams (e.g., Armstrong et al. 1999; Greenberg and Giller 2000; Riley et al. 2002). Subsequent development of multipoint decoders now allows the simultaneous connection of several flat-bed antennas for continuous remote monitoring of individual fish with higher spatial and temporal resolution (Riley et al. 2003).

Using portable PIT readers in conjunction with fixed or stationary PIT antenna designs to locate tags in the channel has been proposed recently (Morhardt et al. 2000; Barbin Zydlewski et al. 2001). Roussel et al. (2000) were the first to field-test a portable system incorporating a 60-cm-diameter antenna that was maneuvered above the stream surface in search of PIT-tagged fish; when used with 3.9-mm × 23.1-mm PIT tags, the equipment had a detection range of 70–100 cm. Until

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[2] Using this technology, Destron Fearing Corporation recently developed a portable detector for sale; however, the unit was unavailable for testing when the present study was undertaken.

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recently, antennas for effectively detecting 12-mm PIT tags were not available, so that fish had to be physically disturbed (e.g., by electrofishing) and recaptured in order to be scanned for tags. Our objective was to construct prototypes of two portable 12-mm PIT tag detectors with higher detection ranges that were based on radio frequency identification systems commercially available in Europe and North America. We also field-tested the efficiency of the new detectors with wild brown trout *Salmo trutta* parr and adult slimy sculpin *Cottus cognatus* to determine their potential for tracking small fish in shallow streams.

Methods

The first prototype was developed from components made in the Netherlands by EID Aalten B.V. (hereafter referred to as EID) to work with Trovan PIT tags (Trovan, Ltd., Douglas, UK). The antenna is composed of one exciter and two receiver coils (Multiple Coils System ANT612; EID) with a filter and an exciter printed circuit board. The components are housed in an octagonal, waterproof PVC box measuring 50 × 40 × 3 cm that is mounted on a 3-m-long aluminum pole connected to the reader. The reader is a full-duplex board (LID650 decoder; EID) interfaced with an LCD screen and powered by a 12-V rechargeable battery. It continuously displays tag code data sent from the antenna, and a piezoelectric buzzer sounds a loud tone to alert the operator whenever a tag is detected. We measured the reading distance of the antenna in the air using the 2.1-mm × 11.5-mm PIT tags (ID100; EID). The tag was moved along a meter stick toward the antenna, noting the distance at which the first reading occurred. We did this with the PIT tag both perpendicular and parallel to the plane created by the antenna in order to examine the effect of tag orientation on reading distance.

The EID portable detector was field-tested in La Roche Brook, a small, second-order tributary of the Oir River (Normandy, France) from 26 to 27 May 2003. The channel width ranged from 1 to 4 m, and substrate mainly consisted of gravel and cobble with occasional occurrences of sand. Since 1993, the brown trout population has been electrofished and the fish individually PIT-tagged in spring and autumn to generate estimations of annual recruitment and fish movement and survival. Six 20-m sections (S1−S6) were enclosed with barrier nets (5-mm mesh) set across the channel, and brown trout parr were removed from each section by electrofishing. The fish were anesthetized in eugenol (0.04 mL/L) and their fork lengths (FLs) measured to the nearest millimeter. Recently emerged age-0 trout were abundant, but they were not PIT-tagged because of their small size (only 20% of these fish were longer than 55 mm FL, the minimum specimen length for tagging; Ombredane et al. 1998). Age-1 trout were scanned to identify individuals that had been tagged in autumn 2002. Untagged fish were marked by injection of an 11.5-mm PIT tag into the peritoneal cavity by means of a hypodermic syringe. After recovery, groups of 10 individually PIT-tagged trout were released into each of the six sections. Fish were given 30 min to adjust to their environment before tracking in every section except S1 (15 min). The operator walked on the stream bank or waded upstream in the section, moving the antenna just above the stream surface from one bankside to the other to detect the PIT-tagged fish. The efficiency of detection was calculated as the percentage of fish detected in the section, each section being surveyed three times successively to estimate the variations in fish detectability between the surveys. Based on 25 randomly spaced point measurements per section, mean water depth ranged from 9.4 cm (S4) to 13.4 cm (S3) and mean velocity ranged from 20 cm/s (S4) to 38 cm/s (S6). Following the same procedure as for age-1 trout, we field-tested the efficiency of the EID portable detector with age-0 trout in six 20-m sections (S7−S12) of La Roche Brook on 22 July 2003. Mean water depth ranged from 8.9 cm (S7) to 10.7 cm (S8) and velocity from 21 cm/s (S10) to 30 cm/s (S9).

The second prototype tested was developed from components made in the USA by Destron Fearing Corporation (hereafter referred to as Destron) using 12-mm PIT tags that are commercially available from Biomark, Inc. (Boise, Idaho) in North America. The antenna consists of a coil of wires attached to capacitors and is enclosed in a flexible thick plastic tubing (38 mm in diameter) that can be bent into an oval shape (33 × 27 cm) with the ends sealed with silicon to make the antenna coil waterproof. The pole of the antenna is made from a 1.65-m length of PVC pipe. The antenna is connected to a tuning box (2001-TU30; Destron) and attached to the PIT tag reader (FS2001/ISO; Destron) powered by a 12-V rechargeable battery. The reader has an LCD display and data logging memory; it displays the tag code sent from the antenna and produces a beeping sound upon detection of a tag. We measured the detection range of the antenna in the air using the

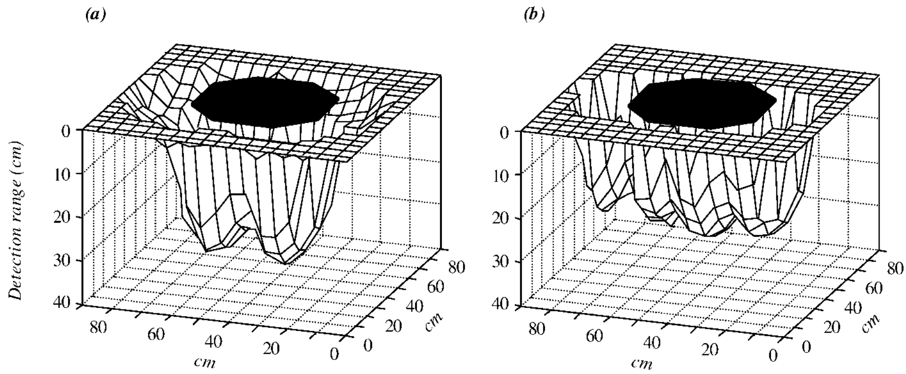

FIGURE 1.—Three-dimensional representations of the magnetic field under the prototype antenna of the EID portable PIT tag detector. The black octagon represents the contour of the antenna. The maximum detection distance ranges from 30 to 36 cm, depending on whether the 12-mm PIT tag has an **(a)** vertical or **(b)** horizontal orientation.

2.1-m × 11.5-mm PIT tags (TX1400ST; Destron). The tag was moved toward the antenna, and we noted the maximum distance at which the reading occurred according to the orientation of the tag (perpendicular or parallel to the plane created by the antenna).

The Destron portable detector was field-tested in three second-order tributaries of the Kennebecasis River (southern New Brunswick)—Windgap Stream (S13), Dee Stream (S14), and Shannon Stream (S15)—from 5 to 21 June 2003. The channel width was similar at all stream sites (3.4–3.6 m on average), the lengths of the sites ranged from 37 to 85 m, and the mean water depths ranged from 17.2 cm (S15) to 24.5 cm (S13). The substrate in these sites consisted mostly of pebble, cobble, and boulders. Each site was electrofished to collect adult slimy sculpin. The sculpin were anesthetized in eugenol (0.04 mL/L) and their total length (TL) measured in millimeters. For all sculpin larger than 60 mm, a small incision (3–4 mm) was made on the ventral surface anterior to the urogenital papilla and the PIT tag was manually inserted into the peritoneal cavity. Following a 24-h recovery period in live boxes set in the stream, 22, 54, and 58 sculpin were released into S13, S14, and S15, respectively. The sites were closed prior to release with barrier nets at both ends. While tracking, the operator walked upstream from one barrier net to the other, moving the antenna in the water close to the stream bottom and ensuring that all areas of the stream were covered within the detection range. The number of tagged sculpin detected during the survey was used to determine the detection efficiency of this system.

Results

The maximum reading distance of the EID portable detector varied from 30 to 36 cm in the air, depending on the orientation of the PIT tag (Figure 1). Reading performances were not affected in water, and the tag was easily read within the substrate (a few centimeters deep in a sand−gravel mixture). Depending on the section, from 46.7 ± 5.8% (mean ± SD) to 86.7 ± 11.6% of age-1 brown trout (FL = 148 ± 26 mm) were detected in La Roche Brook (Figure 2). The efficiency of the system for detecting age-1 brown trout parr was 68.9 ± 15.4%. We detected from 73.3 ± 5.8% to 93.3 ±11.5% of age-0 trout (FL = 72 ± 8 mm), depending on the section, and the efficiency was 81.7 ± 7.5%. With the Destron portable detector, the maximum detection distance ranged from 17 to 30 cm, depending on the orientation of the tag. In the Kennebecasis River, 76–97% of the adult slimy sculpin (TL = 74 ± 9 mm) were detected, depending on the site (Figure 2). The efficiency of the system for detecting tagged sculpin was 81.8 ± 11.9%.

Discussion

The results of the field tests indicate potential advantages and limitations of the new portable 12-mm PIT tag detecting systems. Given their limitations in detection range, their use is restricted to shallow streams. In La Roche Brook, we did not find noticeable variation in water depth between sections, and the maximum water depth was only 32 cm (in section S3) and 30 cm (in section S8). Despite operating in similar water depths, the EID portable detector was more efficient in detecting

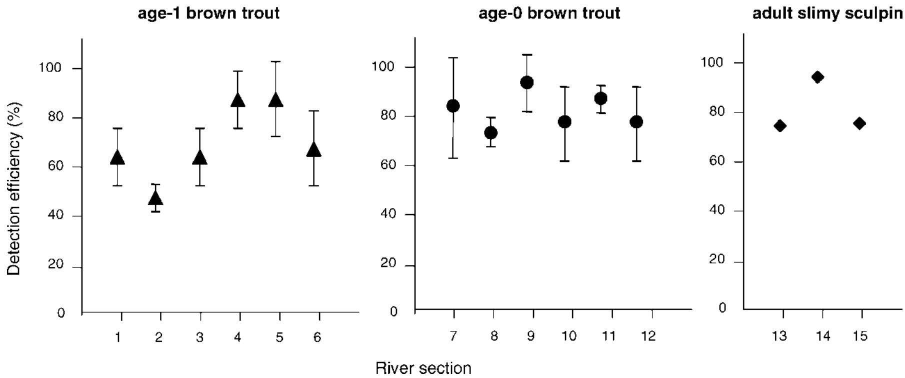

FIGURE 2.—Detection efficiency (mean ± SD) of the two new portable 12-mm PIT tag detectors, given as a percentage of tagged fish detected per tracking survey. The EID prototype was field-tested in La Roche Brook, France, with age-1 and age-0 brown trout (sections 1–12); the Destron prototype was field-tested with adult slimy sculpin (sections 13–15) in the Kennebecasis River, Canada.

age-0 than age-1 brown trout. The increased mobility and wariness of older parr may have affected the relative likelihood of detection because fish were frightened by the antenna and fled the area before they could be detected. This result highlights a major limitation of portable PIT detectors when used on mobile stream fish that display pronounced escape behavior (Roussel et al. 2000). The Destron system was able to detect an average of 82% of the sculpin in small streams despite a lower detection range than the EID system. The difference may be attributable to the behavior of the study species. Cottid fishes like the slimy sculpin are nocturnally active, cryptic, and benthic and have limited mobility (Gray 2003); they normally hide under stones during the day and move only short distances when startled.

Earlier work on Atlantic salmon parr using a portable 23-mm PIT tag detector (Roussel et al. 2000) revealed that the detection efficiency was affected by the presence of dense riparian vegetation (trees and shrubs) and overhanging branches that hampered the operator in moving the antenna. Similarly, fish cover and structural complexity may preclude effective coverage of all potential fish refugia with the antenna. In the present work, we did not conduct a formal study to determine how habitat characteristics may alter the efficiency of detection. However, specific habitat features such as undercut banks in La Roche Brook and boulders in the Kennebecasis River may have accounted for the variations in detection efficiency between sections. In using portable PIT tag detectors to locate fish in a stream section, it is important to realize that the field application of the method is restricted to shallow streams in which the linear distance beneath complex habitat cover does not exceed the detection limits of the antenna.

Despite their limitations, the new portable PIT tag detectors represent an alternative surveying method when standard radiotelemetry is impossible because of small fish size (e.g., age-0 salmonids, most cyprinids, and benthic species of the families Cottidae, Percidae, Cobitidae, and Petromyzontidae). Radiotelemetry batteries for small-bodied fish become exhausted very quickly, and the fish can be encumbered by trailing an emitting antenna such that behavioral effects may be significant (Bridger and Booth 2003). Using portable PIT tag detectors, data can be collected in conjunction with habitat measurements to provide information on the habitat use and hiding microhabitat of PIT-tagged fish in shallow waters without having to physically disturb and handle the individuals. In small streams (<5 m wide), the portable PIT tag detectors can be efficiently operated at a pace that enables the coverage of long distances in a short period of time. In such cases, portable PIT tag detectors will permit more accurate recording of fish positions, movements, and behavior when used with existing stationary antennas and automated PIT interrogation systems. Finally, the new 12-mm PIT tag detectors can be used in terrestrial systems and for many animals with restricted movements in their habitat.

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