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Performance of stationary and portable passive transponder detection systems for monitoring of fish movements

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A stationary system for long-range detection of PIT tags in fish was efficient under high water conditions in streams. A portable system was particularly effective for detecting habitat use by fish without recapture.

Key words: Passive Integrated Transponder (PIT); detection systems; migration; fish movement; TIRIS.

There is growing use of Passive Integrated Transponder (PIT) technology for monitoring individual fish movement and migration (Prentice *et al*., 1990, Armstrong *et al*., 1996; Greenberg & Giller, 2000). Thus far most PIT systems use 12 mm PIT tags. These systems restrict fish movement detection with small tubular coil antennae or through shallow water depths (18 cm), since the range for reading tags is short. Due to these range restrictions, these PIT systems have been restricted largely to laboratory applications (Jenkins & Smith, 1990; Prentice *et al*., 1990; Fängstam, 1993; Brännäs *et al*., 1994; Muir *et al*., 1994; Alanärä & Brännäs, 1997) and limited field applications (Armstrong *et al*., 1996, 1997; Greenberg & Giller, 2000).

Two new systems have been developed for long-range monitoring of fish movements. These systems use Texas Instruments (TIRIS) PIT tags and data-logging transponder readers. One system is stationary and the other is portable. Both systems were tested in the laboratory and field by monitoring movements of parr and smolt Atlantic salmon *Salmo salar* L.

For both systems fish had to be tagged internally with 23 mm long, 3·4 mm diameter, 0·6 g (in air) PIT tags (Texas Instruments model RI-TRP-RRHP; available from Texas Instruments, Dallas, TX 75243). These tags should not be used in fish <8·5 cm L_F without a suture (G. P. Barbin & S. D. McCormick, unpubl. data); sutures are suggested for fish between 6·4 and 8·4 cm L_F (Roussel *et al*., 2000).

A stationary system was used to record the movements of marked fish past a single point, and a portable system to detect individuals in upstream reaches. Analyses of these systems were completed in Smith Brook, Vermont, a small tributary (8 m wide at the stationary site) of the West River, U.S.A.

The stationary system detected tagged fish continuously using two 4 m wide by 1·2 m high coil antennae built to encompass the 8 m width of Smith Brook. The antennae interrogated tags every 100 ms. The entire flow volume was scanned at all discharge levels without obstructing the path of the fish [Fig. 1(a)]. The antennae were constructed as open coil inductor loops with PVC-coated 12-gauge multistrand wire strung through 2·5 cm PVC pipe. Each antenna was connected to a TIRIS S-2000 reader (for details see Castros-Santos *et al*., 1996) powered by two 12 V deep cycle marine batteries (60 A h)

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(a)

(b)

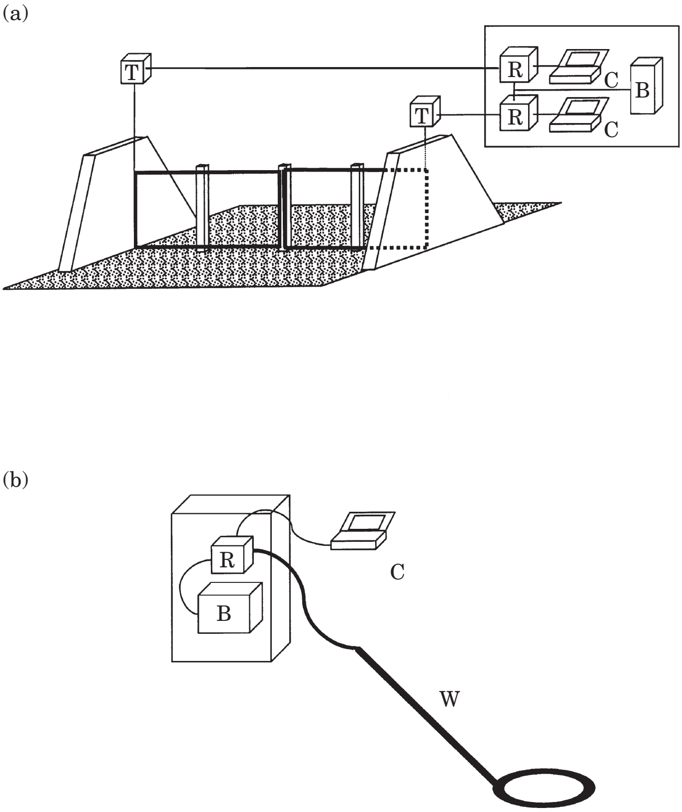

FIG. 1. (a) Schematic representation of the stationary detection system (not to scale) installed between two bridge abutments 4 m apart (bridge omitted for clarity). Two open-loop inductor coil antennae (heavy lines) were connected to tuning circuits (T), which were in turn connected to reader units (R), data-logging computers (C), and batteries (B) housed inside a weatherproof enclosure. Antennae were supported by solid wood columns anchored into the substratum with steel fencing posts. (b) Diagram of the portable detection system (not to scale). Antenna coil (0·5 m diameter) was connected to PVC wand (W) which interfaced to the reader (R) and battery (B) enclosed in the backpack housing. The data-logging computer (C) was carried externally to facilitate reading of detected tag codes.

connected in series; battery run time varied from 2 to 4 days and depended on ambient air temperature. Two palmtop computers (Hewlett Packard HP 200LX) received serial data output from the readers, and a custom programme displayed and logged detected tag IDs and date and time of detection. The readers, batteries and palmtops were contained within a weather-proof box located outside the immediate flood zone of the stream. For operation below 0° C the readers and data-logging computers were enclosed in an insulated box, and a small electric heating element and thermostat prevented the electronic equipment from freezing.

In three consecutive autumns beginning in October 1997, between 200 and 500 age 1+ and age 2+ parr (>9·0 cm L_F) were tagged upstream of the stationary system. The stationary system was operated from April–June 1998 and October 1998 to present to record the spring downstream movements of tagged smolts and seasonal movements of parr.

A portable backpack unit was made using a TIRIS S-2000 reader powered by a sealed 12 V battery (25 A h) that provided *c*. 20 h of continuous run time [Fig. 1(b)]. The reader was connected to an antenna wand 2 m in length with an open coil inductor loop 0·5 m in diameter attached to the end. The antenna wand was constructed of 12-gauge

PVC-jacketed multi-strand wire to form the antenna circuit which was fitted inside 1·5 cm (loop) and 2·5 cm (wand) diameter PVC pipe. A palmtop computer (HP 1000CX) received, displayed, and stored serial data output from the reader as above. The reader and battery were enclosed in a plastic housing that was carried in a small aluminum frame backpack. The palmtop computer was programmed to produce an audio beep whenever tags were detected. Total weight of the entire system was *c*. 10 kg. The range of the system was tested by placing tags at known distances from the antenna loop and scanning the area containing the tag. Reaches upstream of the stationary system were scanned on three occasions, once before (one of the seven tagging sites) and twice after (two of the seven tagging sites) the seasonal spring downstream migration of Atlantic salmon smolts in 1998. Tag detection was tested also in log, rock and ice substrata at depths up to 1 m.

In the laboratory, parr survival after PIT tagging and tag retention for both hatchery and stream-reared parr both exceeded 99% and tagging had no significant effect on growth. To date, parr tagged in the wild exhibit size-at-age comparable with that of untagged parr, confirming that PIT tagging had no significant negative effect on growth.

Using live tagged fish, comparisons with smolts collected in a downstream fixed trap, and tagged drones, the stationary detection system was 93 ± 2% efficient. The maximum reading range of the stationary system antennae was 0·45 m from the plane of the antenna coil. Reading range varied slightly with position and orientation of the tag with respect to the antenna coil; if a tag was passed through the centre of an antenna with its long axis oriented exactly parallel to the antenna plane, it could not be read.

From April to June 1998, 24 individuals (probably smolts) were detected at the stationary system out of 230 parr tagged in October 1997. Although only 10% of the tagged population was detected, many were too small to become smolts and this magnitude of smolt recruitment is within the 9–37% range found in adjacent tributaries of the West River (Whalen *et al*., 2000). Only fish >11·0 cm when tagged in October 1997 were detected migrating as smolts during spring 1998. Twenty of 24 fish moved past the stationary detection system between 25 April and 6 May (Fig. 2). No fish were detected after 6 May. Cumulative smolt detection (or catch) at both the fixed trap and stationary detection system coincided, and the last 60% occurred on a rising temperature. However, movement past the detection system preceded movement into the fixed trap 0·5 km downstream of the detection system, by approximately 1 week (Fig. 2). Because the fixed trap was subject to several washouts at high flows, whereas the stationary system was operable under all flow conditions, it was concluded that the stationary system provided a more accurate representation of smolt migration timing in the study tributary.

The portable detection system could read tags at through-water distances up to 0·5 m when the long axis of the tag was oriented perpendicular to the plane of the antenna loop, and up to 0·3 m when the tag was oriented parallel to the loop plane. Tags could be detected through logs, rocks, cobble and ice with little or no loss in detection range.

Most tagged parr could be detected within a 10 cm^2 area of the wand loop. Twenty-seven of 32 tags detected in two of the original tagging sites scanned after the seasonal smolt migration changed position after one sweep of the area, indicating the tag was within a live fish. Five tags did not move when rocks were moved manually to locate the tag as a live fish. It is possible that these represented stationary fish, lost tags or dead fish. However, one of the stationary tags was detected subsequently downstream at the stationary detection system later in the season. The 32 fish detected were the smaller (10·7 ± 0·2 cm, $n=32$) individuals tagged the previous autumn (11·4 ± 0·05 cm, $n=683$, $P<0{\cdot}001$ Mann–Whitney rank sum test). In conjunction with the stationary system, *c*. 50% of the fish from each of the sites scanned with the portable system could be accounted for.

There were multiple advantages and few disadvantages to these new PIT tag detection systems. The stationary system was rarely restricted by climatic conditions that limited or precluded the use of flat-bed arrays, traps, weirs, snorkeling surveys and electrofishing, for monitoring fish behaviour and movements. As described by Castro-Santos *et al*. (1996), systems using large PIT tags have the advantage of larger reading distances, which enable monitoring of fish in water depths >1 m without restricting or disrupting their movement. Both systems also have simple antenna designs and installation procedures.

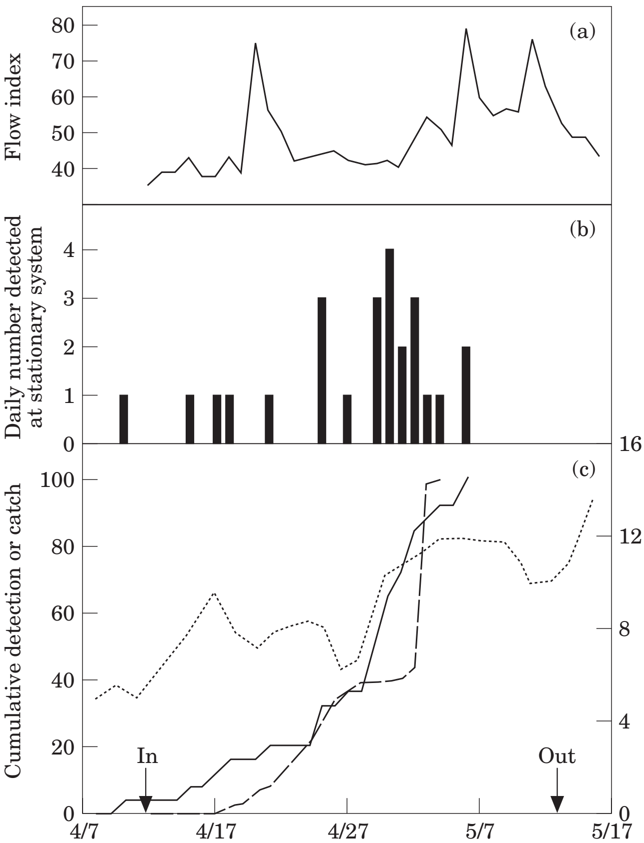

FIG. 2. (a) Flow index (river stage height at the location of the trap); (b) Atlantic salmon movement (daily number detected at stationary system) and (c) cumulative detection or catch and water temperature (. . . .) recorded at the stationary system (——) and smolt trap (– – –) for spring 1998. ' In ' and ' Out ' indicate the dates when the smolt trap was operational in Smith Brook.

Larger detection antennae for the portable system can be designed, and a prototype portable detection system 4 m by 1 m in size has been used successfully to scan large sections of streambed (J-M. Roussel & R. A. Cunjak, pers. comm.). Both systems have minimal power requirements (1 A continuous current draw per reader operating at 12 V) making them appropriate for the field.

Limitations of these systems include the inability to examine fish for growth or physiological parameters; inability to distinguish two fish in the antenna field at the same time; lack of detection of tags oriented in rare positions; and the need to use slightly larger fish due to tag size. However, when used in conjunction with other systems, such as traps, these systems can provide detailed data on the behaviour, physiology and ecology of fishes.

These techniques provide new tools for analysing multiple aspects of migratory and non-migratory fishes. Their utility has been shown for examining movements of Atlantic salmon parr, but other uses include estimating winter survival, migration timing between two or more stationary systems, overall migratory run timing to and between passage structures and monitoring fine-scale spatial movements of juveniles to assess microhabitat preference variables. These techniques can be applied also to most animal groups to examine habitat utilization, movement and migratory patterns.

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