# Field test of a new method for tracking small fishes in shallow rivers using passive integrated transponder (PIT) technology[1]

**J.-M. Roussel, A. Haro, and R.A. Cunjak**

**Abstract**: A new method for tracking small fishes in shallow streams based on passive integrated transponder (PIT) technology, using a portable reading unit, was investigated. The device consists of a chest-mounted palmtop computer, a reader, and a 12-V battery enclosed in a backpack, connected to a 60-cm-diameter coil antenna mounted on a 4-m-long pole. The method was field tested with wild Atlantic salmon, *Salmo salar*, parr using transponders 23.1 mm long and 3.9 mm in diameter surgically implanted in the peritoneal cavity of the fish. Laboratory experiments indicated no posttagging mortality for fish > 84 mm in fork length and no tag loss when sutures were used. In the field, tag detection distance was up to 1 m. While moving the antenna above the stream surface, the operator could locate a fish's position to within a square metre. Experiments indicated that more than 80% of tagged parr, on average, were detected by the reader. The technique is a useful alternative to standard radiotelemetry in small-scale environments because PIT tags can be implanted in smaller-bodied fishes and fine-scale movements of individuals can be studied. It can be applied to address numerous questions in the fields of animal behaviour, habitat use, and population dynamics.

**Résumé** : S'appuyant sur la technologie PIT (passive integrated transponder), une nouvelle méthode est proposée pour le pistage de poissons de petite taille en rivière peu profonde. L'unité portable de détection se compose d'un ordinateur de poche, d'une batterie de 12 V et d'un module de lecture, connecté à un câble enroulé formant une antenne de 60 cm de diamètre. L'ordinateur est porté à la ceinture, le lecteur et la batterie dans un sac à dos, et l'antenne que manipule l'opérateur est fixée au bout d'une perche de 4 m de long. La méthode a été testée in situ sur des juvéniles de saumon atlantique, *Salmo salar*, avec des transpondeurs de 23,1 mm de long et 3,9 mm de diamètre implantés chirurgicalement dans la cavité péritonéale. Des tests en laboratoire ont indiqué l'absence de mortalité pour les poissons de taille supérieure à 84 mm (longueur fourche), aucun rejet du transpondeur n'étant enregistré lorsqu'une suture est faite. Sur le terrain, le poisson peut être détecté jusqu'à un mètre de distance : en balayant de l'antenne la surface de l'eau, l'opérateur peut déterminer sa position avec une précision de l'ordre du mètre carré. Les essais indiquent que, en moyenne, plus de 80% des poissons sont détectés. Cette méthode est une alternative utile à la radio-télémétrie classique, car des individus de petite taille peuvent être équipés pour suivre des déplacements de courte amplitude. Elle peut permettre d'aborder de nombreuses questions relatives au comportement du poisson, à son habitat et à la dynamique de population d'une espèce.

## Introduction

Studying movement and habitat use by individual fish in streams is usually required to address the functional mechanisms in fish–habitat relationships. Although radiotelemetry is commonly used for large-bodied and mobile fishes, the size of the transmitter and its antenna preclude any study on small individuals. For salmonids, Adams et al. (1998) noted an impact on swimming ability of juvenile chinook salmon (*Oncorynchus tshawytscha*) and consequently recommended against implanting transmitters in fish < 120 mm in fork length (FL). In the past decade, the passive integrated transponder (PIT) technology has been developed as a novel method for individually tagging fish (Prentice et al. 1990). The tag consists of an integrated circuit chip, capacitor, and antenna coil encapsulated in a glass cylinder, and its operation requires an external energy source. An electromagnetic field generated by the reading unit induces current in the an-

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tenna coil that energizes the integrated circuit, which transmits its signal to the reader. Tag detection range depends on the size and orientation of the tag antenna coil and the overall size of the tag. Typical length dimensions of commercially available implantable PIT tags vary from 11 to 32 mm; therefore, PIT tags can be implanted in the peritoneal cavity of small fish, such as young salmonids. Focusing on movement of fish in running waters, recent advancements have led to the development of stationary and automatic reading units, such as flat-bed antennae (Armstrong et al. 1996) or electronic weirs (Castro-Santos et al. 1996; Barbin-Zydlewski et al., U.S. Fish and Wildlife Service, Abernathy Fish Technology Center, Longview, Wash., unpublished data). With such technological improvements, it has become possible to design mobile reading units for monitoring small-scale movements of fish in shallow streams. In this paper, we describe the use of PIT technology to study diel movements and habitat use by age-1 and older Atlantic salmon parr (*Salmo salar*), with special regard for testing its efficiency to detect and locate individuals in two streams.

## Materials and methods

### Tagging method and laboratory experiment

The PIT tags used for the tests were 23.1 mm long, 3.9 mm in diameter, weighed 0.6 g in air, and were manufactured by Texas Instruments (TIRIS series 2000; RI-TRP-WRHP). Initially, 33 hatchery-reared Atlantic salmon parr 64–94 mm FL were used to determine size-dependant effects of implanting PIT tags. Fish were held in two indoor Fiberglas tanks (100 L, 75 cm in diameter, 25 cm deep) at the University of New Brunswick. Artificial fluorescent lighting was provided, beginning at 5:00 and ending at 20:00. Each tank was supplied with well water at 12°C–13.5°C with 68%–91% of oxygen saturation. The water flow was maintained at the minimum amount needed to produce a circular current in the tanks. Fish were fed on standard-grade food pellets at a rate of at least 3.3% of body weight per day, but no food was delivered 24 h before and after tagging. For surgery, fish were individually anesthetized in a solution of phenoxyethanol (0.03%). A 4-mm-long incision was made on the midventral line starting 15–20 mm anterior to the pelvic girdle, deep enough to penetrate the peritoneum. The transponder was then implanted, gently pushing it posteriorly within the cavity. The incision was closed with one simple, interrupted non-absorbable surgical suture (Ethicon silk braided, 6-0 taper C-1 needle) in the middle of the incision (Summerfelt and Smith 1990). The suture was used for only 15 of the 33 parr tagged. Antibacterial ointment (Polymyxin B) was applied to the incision to prevent infection.

Thirty-two days after tagging, seven parr had died (21.2%). All mortalities were parr < 84 mm FL. Among the 26 surviving parr, five had lost their tag (15.2%); however, no tag loss was recorded when sutures were used. The incision was well healed for each of the 21 remaining tagged parr.

### Portable reading unit

The portable reading unit was constructed using a commercially available radio frequency identification system (Texas Instruments TIRIS S-2000). The system consisted of a half-duplex reader module (TIRIS RI-RFM-008) operating at 134.2 kHz, connected to a control module (TIRIS RI-CTL-MB2A). The reader/control modules were powered by a rechargeable 12-V DC lead–acid battery that provided approximately 2 days of continuous run time on a single charge. Both modules were housed in a plastic box 25 cm long x 15 cm wide x 15 cm deep. The instrumentation box and battery were enclosed in a small rigid-frame backpack. The reader module was connected to an open loop inductor antenna that both generated an energizing electromagnetic field and received transmitted signals from the tag. The antenna was constructed using 12-gauge insulated THHN multistrand wire; the wire was wound to form a 60-cm-diameter inductor coil (6 loops), and its two extremities (5 m in length) were connected to the reading module. The inductor coil was tied to a square PVC tubing frame and mounted on a wooden pole 4 m in length so as to be rigid and to facilitate the handling of the antenna. A bank of tuning capacitors (TIRIS RI-ACC-008) was connected to the circuit between the wand and the reader module and was housed in the backpack; selection of combinations of capacitors allowed the antenna circuit to be tuned to the resonant frequency. A palmtop computer (Hewlett Packard HP200LX) was connected to the control module via an RS-232 serial cable. A custom software program (written in BASIC language) continuously displayed and logged tag code data sent from the control module via the RS-232 interface, along with date and time information. The palmtop computer was housed in a transparent plastic box and carried outside of the backpack (usually chest-mounted) so that the operator could easily read detected tag codes as they were displayed. A piezoelectric buzzer was also connected to an alarm circuit on the control module, which sounded a loud tone whenever a tag was detected in the antenna field. The total weight of the complete system was approximately 12 kg. The design of the portable reading unit was adapted from Barbin-Zydlewski et al. (U.S. Fish and Wildlife Service, Abernathy Fish Technology Center, Longview, Wash., unpublished data).

The detection range (measured as the distance between the plane of the antenna loop and the tag, while holding the antenna horizontally above a PIT tag) varied with the orientation of the tag: up to 70 cm when the tag was horizontal and up to 100 cm when the tag was vertical. The tag was easily read in the water and within the substrate (up to 20 cm deep in a cobble–gravel mixture) without consequence to detection efficiency. Any transponder that entered into the antenna field for at least 100 ms was detected. The efficiency of the portable device to detect and locate a fish was evaluated in two shallow-water tributaries of the Little South West Miramichi River (N.B), Otter Brook, and Catamaran Brook, each offering natural but contrasting habitat conditions for Atlantic salmon parr.

## Field test of the efficiency of the device

Otter Brook is a small second-order tributary. Channel width ranges from 2 to 4 m and mean gradient is 1.2%. The brook is characterised by the presence of woody debris in the channel, rocky substrate, and a complete canopy of overhanging trees and branches. A 25-m-long riffle-run sequence (mean width 3.1 m) was enclosed with two barrier nets (5-mm mesh) set up across the channel. Based on 69 evenly spaced measurements in the site, mean and maximum water depths were 12 cm and 33 cm, respectively.

On 23 June 1999, Atlantic salmon parr were captured in the site using a backpack electrofisher (Smith-Root type 12, 500 V, 60 Hz). According to the laboratory findings, PIT tags were implanted in 23 parr > 84 mm FL (representing 3.8–9.7% of the fish's body weight), and a suture was used for each individual. Fish were then released back into the site, between the two barrier nets. On 30 June and 1 July 1999, tagged fish were tracked six times during daylight hours. When tracking, the operator walked in an upstream direction on the stream bank, from one barrier net to the other, moving the antenna just above the stream surface from one bankside to the other. The number of fish detected per tracking varied from 17 (73.9%) to 21 (95.6%). On average, the efficiency of the reader for detecting tagged parr was 81.9%.

The second test was performed in the lower reach of Catamaran Brook, where the mean gradient is 0.6% and the channel is 6–13 m wide. Since 1990, a fish counting fence at the mouth of the brook has been operated to monitor Atlantic salmon movement (Hardie et al. 1998). Approximately 50 m upstream of the counting fence, a 72-m-long site (7.5 m wide on average) was marked out with flags set every metre on both banks. The site consisted of a riffle-run succession where mean water depth was 21 cm (estimated from 360 measurements); maximum depth was 79 cm. The study site was electrofished on 10 July, 12 July, and 25 July 1999. PIT tags (representing 3.2–10.0% of the fish's body weight) were implanted in 46 fish > 84 mm FL, using the same procedure as for Otter Brook (above). As no barrier nets were used here, the fish were free to move from the site after release.

In total, five fish were trapped at the counting fence within 48 h after tagging. On 2 August 1999, three individuals were detected within a 50-m zone outside the site boundaries. One of the PIT tags was found on the stream bank of the site; the fish carrying the tag was apparently killed by a mink, *Mustella vison*. The efficiency of the reader was calculated, therefore, assuming that a maximum of 37 fish were present in the site. From 2–7 August 1999, the tagged parr were tracked in the site six times during daylight and six times at night. The operator waded upstream, moving the antenna just above the stream surface and from one bankside to the other. The antenna was moved underwater only in the deepest habitats (>60 cm) to detect fish on the streambed. The number of fish recorded varied from 31 (83.8%) to 34 (91.9%) during daylight hours (87.3% in average) and from 32 (86.5%) to 34 (91.9%) at night (88.3% in average).

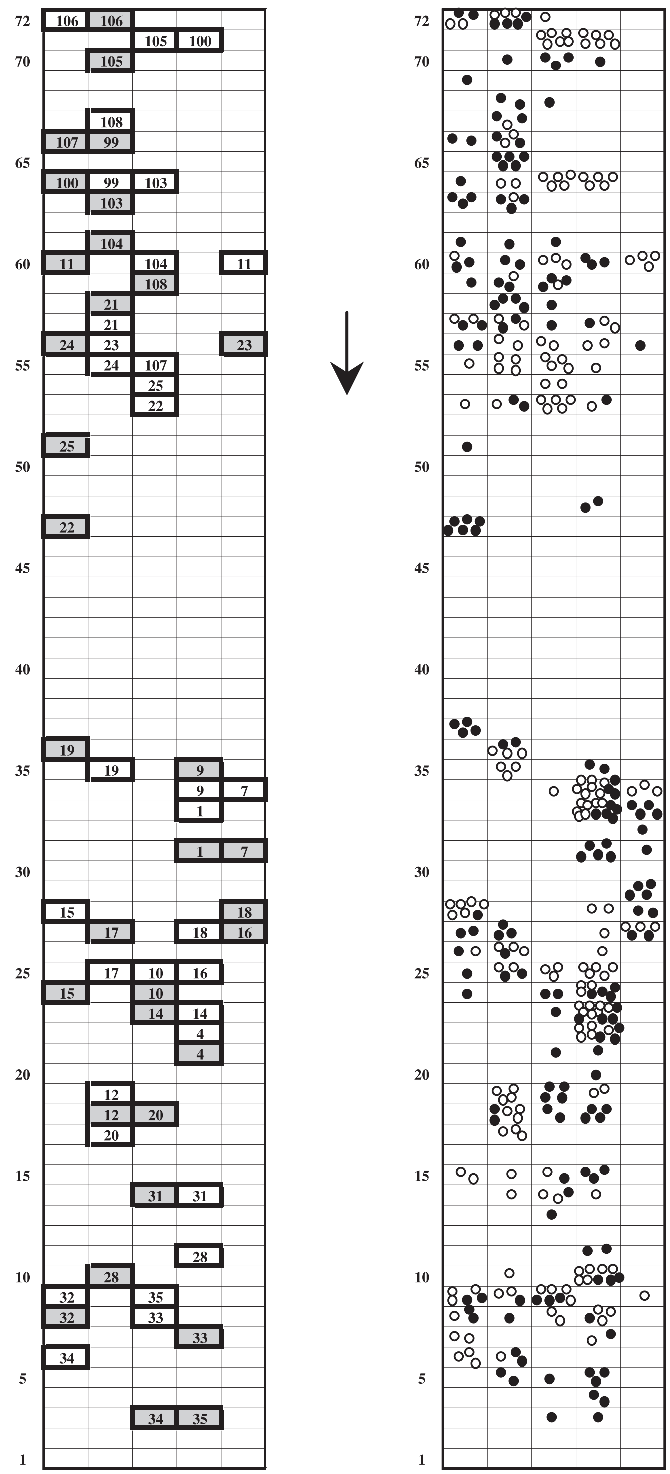
Tracking surveys were comparatively easier in Catamaran Brook than in Otter Brook as no woody debris or overhanging trees and branches hampered the operator when handling the antenna. The few parr not recorded during a tracking were likely holding stations in microhabitat not accessible to the operator. Indeed, access to all available in-stream habitats was the major limitation of the method.

Consecutive trackings in Catamaran Brook did not provide any evidence of tag loss or fish mortality after tagging as each PIT tag was detected in several locations within the site during the experiment. Preliminary data for the growth of tagged parr in this study indicate that except for one individual, fish grew from 1 to 8 mm during the period of July to September. This corresponds to the average growth typically observed during mid-summer for parr > 84 mm in Catamaran Brook (R.A. Cunjak, unpublished data). It appears, therefore, that implanting the transponder did not induce a negative effect on fish growth as also noted for other salmonid species under different conditions (Prentice et al. 1990; Ombredane et al. 1998).

## Potential applications and interests

Once a fish was detected in Catamaran Brook, its position in the channel was plotted in accordance with the flags along the banks and by visually dividing the stream width into 5

**Fig. 1.** Location of PIT-tagged Atlantic salmon parr in Catamaran Brook, as determined by a portable reader. Numbers from 1 to 72 represent metres along the site, whereas the channel width is divided into five equal-sized cells. The arrow indicates the flow direction. Left: results from two consecutive tracking surveys, during daytime (open cell) and the following night (shaded cell). Numbers in cells indicate tag codes that identify and locate individuals. Right: spatial distribution of fish within the site, resulting from the six daytime (open circles) and the six nighttime (solid circles) trackings.



cells. Occasionally at night, direct observations of fish detected in low velocity habitats along the stream edge confirmed that the operator was able to locate the fish to within a square metre. Results from the successive tracking surveys in Catamaran Brook (Fig. 1) demonstrated how the mobile reader could be used to track parr implanted with PIT tags in shallow-water streams.

Further improvements are needed to increase the detection range of the portable reading unit. For the moment, the new tracking method is limited to shallow-water streams (<1 m deep) and to species that allow the operator to get fairly close. However, it represents a useful alternative to standard radiotelemetry because PIT tags can be implanted in smaller-bodied fishes and fine-scale movements of individuals can be studied. Moreover, one tag costs less than US$7, making it possible to mark a large number of individuals in the wild. Therefore, the method can be applied to address numerous questions related to animal behaviour and habitat, from fine-scale movements of individuals in the channel to spatial distribution of a local population. The data can also be interfaced with habitat measurements to describe habitat use by individuals and by a species in general. In the case of species that live in deeper habitats, waterproof reading units can be designed for snorkeling or for scuba diving experiments. Unlike radio transmitters, PIT tags do not require batteries to operate. An operational life of 10 years or more is expected and the method, therefore, could be useful for linking the life history of individuals to the dynamics of a population, especially for salmonids. Lastly, the applications of the new tracking method need not be restricted to fish but can be used for many animals with restricted movements in their habitat.

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