EFFECT OF IMPLANTING A PASSIVE INTEGRATED TRANSPONDER TAG IN JUVENILE CHUB, *SQUALIUS CEPHALUS* (L.), ON THEIR CONDITION, GROWTH AND SURVIVAL

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ABSTRACT

The effect of implanting a Passive Integrated Transponder (PIT) tag on the survival, growth and condition of a small cyprinid, juvenile chub *Squalius cephalus* (L.) with a mean weight of 2.4 g was studied in the laboratory. During this experiment, which lasted for 31 days, 80 specimens were tagged. The changes in Fulton's condition factor (K), specific growth rate of mass (G_M) and specific increase in length (L_S) were evaluated. The results showed that implanting PIT tags did not affect the survival or growth of the fish; however, it had a negative effect on their condition. The initial size of the fish had a significant effect on the specific growth rate in terms of mass, but not in terms of length. Survival was 98.8% and tag retention 97.5%, when the tag made up 4.3% of the mass of the fish. These results demonstrate that PIT tagging is an appropriate method for chub heavier than 2 g. For this size category, we recommend that PIT tagging is suitable when the tag makes up 4.3% of the body mass of the individuals.

Keywords: condition; cyprinids; PIT tags; specific growth rate; tagging effect

Introduction

Passive integrated transponder (PIT) tags are used increasingly in both commercial aquaculture and ecological studies on fish (Alanärä et al. 2001; Fischer et al. 2001; Bolland et al. 2009a; Grieve et al. 2018). PIT tagging has become one of the most effective tools for identification of individuals and, due to their relatively low cost and automatic data collection options, they enable a large number of fish to be marked and detected with high reliability. Furthermore, the weight and size of PIT tags make them ideal for studying juveniles or small species of fish (Thorstad et al. 2013; Jørgensen et al. 2017). Although this tagging method is almost universally applicable, size and species-specific adverse effects have been reported (Roussel et al. 2000; Pennock et al. 2016). Careful evaluation of the effects of PIT tagging on a wide range of fish of different sizes is urgently required (Ficke et al. 2012).

Juvenile cyprinids weighing only a few grams have received little attention in this context. For cyprinids, tag retention and the survival of tagged individuals has been evaluated previously for the genus *Squalius* (e.g. Bolland et al. 2009b; Pires et al. 2010). For example, Bolland et al. (2009b) report the effects of PIT tags in terms of mortality and retention in large *Squalius cephalus* (L.). In the study of Pires et al. (2010) survival, tag retention and swimming performance are evaluated for an endangered Iberian cyprinid, Mira chub *Squalius torgalensis* (Coelho et al. 1998). The objective of the present study was to extend the work on small cyprinids, focusing on both retention and survival, and growth, weight and condition of juvenile chub *Squalius cephalus* (L.) after implanting PIT tags.

Materials and Methods

Chub is a common omnivorous cyprinid inhabiting European rivers, with a wide ecological amplitude and known migratory and daily activity patterns (Lucas and Baras 2000). The fish used in this experiment were hatchery-reared juvenile chub, *Squalius cephalus* (L.), obtained from a local fish supplier (Czech Fishery Ltd., Czech Republic). A total of 160 fish of a similar size were randomly distributed among four separate holding tanks (300 l each; natural photoperiod; conditions in all tanks: temperature 19.1 ± 0.5 °C; conductivity 314 ± 6.9 μS cm^{-1}) and acclimated for 3 weeks prior to the start of the experiment. Fish were fed daily with dry fish flake food. In order to ensure good water quality, one third of the water in each tank was changed each week.

Fish from two randomly selected holding tanks (80 specimens) were tagged at the beginning of the experiment, after first anaesthetising them with 2-phenoxy-ethanol (0.2 ml l^{-1}; Merck KGaA, Germany). Fish were measured (L_S; standard length, mean 54 mm, range 47–64 mm), weighed (M; mean body mass 2.37 g, range 1.44–4.24 g), and then PIT tags (Trovan ID100, 0.1 g in air, 12 × 2.1 mm) were inserted into the abdominal cavity using a hypodermic needle attached to a syringe. The tag to body mass ratio varied from 2.36 to 6.95% (mean 4.25%). The fish placed in the two other holding tanks were left undisturbed to serve as controls (Skov et al.

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Table 1 The initial and final lengths (L_S), masses (M) and condition (K) of PIT tagged and control specimens of chub, *Squalius cephalus*.

Treatment	Mean ± S.E.	Mean ± S.E.	Mean ± S.E.	Mean ± S.E.	Mean ± S.E.	Mean ± S.E.
	initial L_S (mm)	final L_S (mm)	initial M (g)	final M (g)	initial K	final K
Control		56.3 ± 0.4		2.92 ± 0.06		1.63 ± 0.01
PIT tags	53.6± 0.4	56.8 ± 0.4	2.37± 0.06	2.85 ± 0.06	1.53 ± 0.02	1.54 ± 0.01

2005). During the experimental period, which lasted for 31 days, all fish were kept under the same regime with daily monitoring to detect tag expulsion or death. At the end of the experiment, all fish were anaesthetised, measured and weighed. All experimental procedures complied with relevant legislative regulations (Law no. 246/1992, §19, art. 1, letter c).

The specific growth rate (GM) in terms of mass (proportional increase/day) was calculated according to the formula: $GM = 100(\ln M_2 - \ln M_1)\, t^{-1}$, where M_1 and M_2 are the masses (g) at the start and end of the study period, respectively, and t is the length of the period in days. The increase in L_S (GL) was calculated similarly (Jepsen et al. 2008). The changes and differences in Fulton's condition factor (K) were evaluated as: $K = M\, L_S^{-3}$, where M is mass and L_S is the standard length (mm).

Statistical analyses were performed using the SAS software package (SAS Institute Inc., version 9.2, www.sas.com). Standard length, mass, Fulton's condition factor, specific growth rate and increase in length were analysed using separate mixed models with random factors (PROC MIXED). Random effects were used to account for repeated measures collected for the same experimental units (individual fish) throughout the duration of the study. The significance of an exploratory variable (i.e., tagging treatment) in a particular model was assessed using a F-test. Differences between the classes were tested using a t-test (Tukey–Kramer adjustment for multiple comparisons) and the degrees of freedom calculated using the Kenward–Roger method.

Results

The smallest individual (1.44 g) in which a PIT tag was implanted died the following day. Post mortem examination revealed contusion of the internal organs. The remaining 79 tagged fish survived, resulting in a survival of 98.8%. One fish (1.75 g) expelled its tag during the third week of the experiment, so tag retention was 97.5%.

The PIT tagged fish grew significantly (mass $F_{2,135} = 90.99$, $p < 0.0001$, Fig. 1a; length $F_{2,137} = 149.3$, $p < 0.0001$, Fig. 1b) during the experimental period, and their final size did not differ from that of the control fish (mass *Adj* $p > 0.63$; length *Adj* $p > 0.54$, Table 1), indicating that PIT tagging did not affect the growth of the juvenile chub. The condition of the PIT tagged fish remained the same throughout the experiment ($F_{2,138} = 16.52$, $p < 0.0001$, *Adj* $p > 0.66$, Fig. 1c), but was poorer at the end of the experiment than that of the control fish (*Adj* $p < 0.0001$), which indicates that PIT tagging had a negative effect on fish condition. The tag to body mass ratio had a significant effect on growth in mass ($F_{1,75} = 3.66$, $p < 0.05$, Fig. 2), but not on increase in length ($F_{1,75} = 0.19$, $p > 0.66$); *i.e.* smaller fish had a higher specific growth rate of mass.

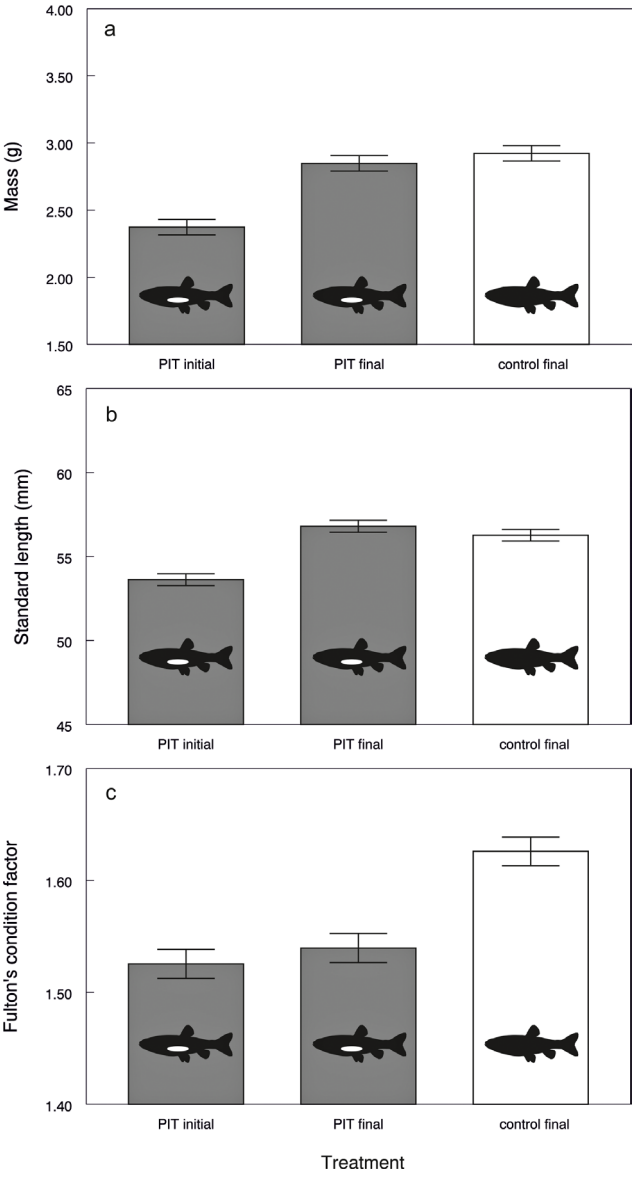

Fig. 1 Initial and final mass (a), length (b) and condition (c) of tagged and control chub. Initial and final values for PIT tagged chub, *Squalius cephalus,* and final values for control fish are adjusted means ± SE.

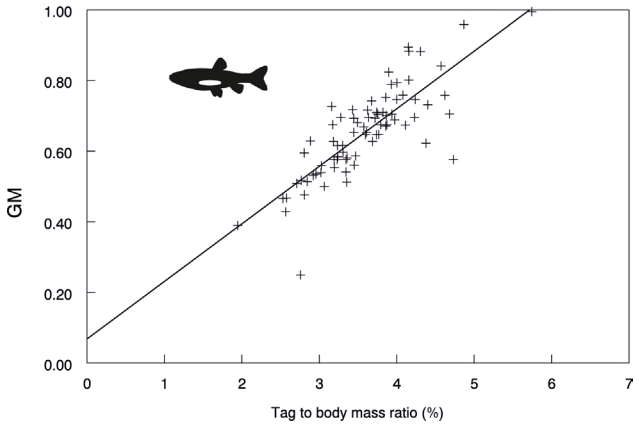

Fig. 2 Relationship between specific growth rate of mass (GM) and the tag to body mass ratio in juvenile chub, *Squalius cephalus*.

Discussion

Small fish are more likely to suffer adverse effects from tagging (Jepsen et al. 2008). Based on the present study, it is recommended that the minimum weight for tagging chub with PIT tags is 2 grams, as no fish above this weight lost the tag or died during the experimental period. Tag retention and survival of tagged fish is closely associated with the tag to body mass ratio (Pennock et al. 2016). In order to minimize the effect of tagging a tag to body mass ratio of less than 2% is often recommended when determining the minimum size of fish to be tagged (Winter 1983; Jepsen et al. 2005). Although this ratio is still used, a number of recent studies have challenged this view and report no or minimal effects of tag to body mass ratios of up to ~10% (Ficke et al. 2012; Ward et al. 2015; Pennock et al. 2016). In this study, juvenile chub implanted with tags that made up 4.3% of their mass were successfully tagged and 98.8% survived with negligible effects. Other studies assessing survival and tag retention by small cyprinids under laboratory conditions report tags that make up to 3.94% of the mass of the fish result in acceptable levels of post-implantation survival (e.g. Skov et al. 2005; Bolland et al. 2009a; Ficke et al. 2012; but see Pennock et al. 2016). All of the flathead chub, *Platygobio gracilis,* implanted with PIT tags that made up 3.94% of their mass survived (Richardson 1836) (Ficke et al. 2012), 96.3% of European chub implanted with tags that made up 2–6% of their mas survived (Bolland et al. 2009a) and 99% of roach, *Rutilus rutilus* (L.), implanted with tags that made up 2.91% of their mass survived. The higher tag to body mass ratios used in some other studies, e.g. 3.8% for creek chub (Bangs et al. 2013), 6.3% for southern redbelly dace, *Chrosomus erythrogaster* (Rafinesque 1820) (Pennock et al. 2016) and up to 12.5% for humpback chub *Gila cypha* (Miller 1946) (Ward et al. 2015), however, are associated with significant reductions in survival (survival between 62.5% and 82%).

At the end of this study, the condition of PIT tagged chub was poorer than that of the controls. This could be a consequence of the energetic costs associated with recovering from the effects of the operation (Jepsen et al. 2008), but the handling and the surgery could also have influenced the observed trends. Capture and handling stress may have different effects on different species of fish. For example, Skov et al. (2005) reports it did affect the condition of PIT tagged rudd, *Scardinius erythrophthalmus* (L.), but not roach *Rutilus rutilus* (L.). The weight of tagged Mira chub (Pires et al. 2010) is also lighter 30 days post tagging. Our results indicate that it is possible to implant PIT tags in small cyprinids weighing more than 2 g. For this size category we recommend the tag should not make up more than 4.3% of the mass of the fish.

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