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INFLUENCE OF PIT TAGS ON GROWTH AND SURVIVAL OF BANDED SCULPIN (*COTTUS CAROLINAE*): IMPLICATIONS FOR ENDANGERED GROTTO SCULPIN (*COTTUS SPECUS*)

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Abstract: To make appropriate restoration decisions, fisheries scientists must be knowledgeable about life history, population dynamics, and ecological role of a species of interest. However, acquisition of such information is considerably more challenging for species with low abundance and that occupy difficult to sample habitats. One such species that inhabits areas that are difficult to sample is the recently listed endangered, cave-dwelling grotto sculpin, *Cottus specus*. To understand more about the grotto sculpin's ecological function and quantify its population demographics, a mark-recapture study is warranted. However, the effects of PIT tagging on grotto sculpin are unknown, so a passive integrated transponder (PIT) tagging study was performed. Banded sculpin, *Cottus carolinae,* were used as a surrogate for grotto sculpin due to genetic and morphological similarities. Banded sculpin were implanted with 8.3 × 1.4 mm and 12.0 × 2.15 mm PIT tags to determine tag retention rates, growth, and mortality. Our results suggest sculpin species of the genus *Cottus* implanted with 8.3 × 1.4 mm tags exhibited higher growth, survival, and tag retention rates than those implanted with 12.0 × 2.15 mm tags. To this end, we recommend 8.3 × 1.4 mm PIT tags as a feasible option for tagging adult sculpin (> 60 mm total length) with minimal impacts on growth and mortality.

Introduction

Previous researchers have used mark-recapture studies to evaluate fish population dynamics (Hamel et al., 2015; Ruetz III et al., 2015). Data garnered from these studies generally include measures of growth, movement, habitat use, and survival, all of which are imperative for fisheries conservation or restoration (Hamel et al., 2015; Ruetz III et al., 2015). However, obtaining these data requires utilization of batch marking or individual recognition methods, which can be problematic, especially on small fishes (Baras et al., 1999; Brown et al., 1999; Skalski et al., 2009). One promising technique used to mark small fishes is passive integrated transponder (PIT) tags, which alleviate issues associated with size and provide an individual marker for fish (Ruetz III et al., 2006; Skalski et al., 2009; Tatara, 2009; Fuller and McEntire, 2013). The use of PIT tags can provide a more thorough understanding of stream fish ecology (e.g., Bruyndoncx et al., 2002; Knaepkens et al., 2004; Cucherousset et al., 2005; Cunjak et al., 2005) relative to more traditional techniques (Gibbons and Andrews, 2004).

With the ability to uniquely mark small individuals, PIT tags have major advantages over other current marking techniques (Gibbons and Andrews, 2004; Skalski et al., 2009; Fuller and McEntire, 2013). However, apprehension often surrounds tagging small individuals because of high tag-to-body mass ratios (Winter, 1983; Winter, 1996; Baras et al., 1999; Brown et al., 1999; Jepsen et al., 2005; Ruetz III et al., 2006). A critical assumption for tagging studies is that tags do not change behavior, growth, or mortality of marked fish (Nielsen, 1992; Gibbons and Andrews, 2004; Ruetz III et al., 2006). Studies have supported this supposition by demonstrating that PIT tags do not strongly affect growth and mortality of small fishes (Prentice et al., 1990; Quartararo and Bell, 1992; Ombredane et al., 1998; McCormick and Smith, 2004). Despite minimal effects, PIT tagging results can vary depending on tag size, tag-insertion procedure, species tagged, and size of individuals being tagged (Hirt-Chabbert and Young, 2012; Fuller and McEntire, 2013). Due to disagreements among prior researchers about effects on small-bodied fishes and a lack of information regarding effects on non-salmonid species, additional information on the influence of PIT tagging on small-bodied fishes is warranted.

Such small-bodied fish include freshwater sculpin species that are widespread throughout the Northern Hemisphere (Ruetz III et al., 2006). Within this vast range, sculpins play intricate roles in small-stream food webs that are crucial to maintaining ecological integrity (Kohler and McPeek, 1989; Dahl, 1998; Miyasaka and Nakano, 1999; Ruetz et al., 2006; DeBoer et al., 2015). Although considered an important species to small-stream ecosystems, minimal information exists for some sculpin species such as the grotto sculpin. The grotto sculpin, *Cottus specus*, is one sculpin species that is in need of research. Grotto sculpin are an endangered, cave dwelling species only found in Perry County, Missouri. The cave environment that this species occupies, as well as its

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endangered status, inhibits the ability to work directly with the species; and therefore, a surrogate species is necessary. Banded sculpin, *Cottus carolinae*, are closely related genetically and morphologically, with similar reproductive ecology, foraging behavior, and diet (Jason Crites, unpublished data). As such, banded sculpin were used as a surrogate species to provide insight into the feasibility of PIT-tag use to evaluate population metrics for grotto sculpin. The objectives of our study were to evaluate PIT tag retention and estimate survival and growth of tagged banded sculpin using two different sizes of PIT tags, 8.3 × 1.4 mm and 12.0 × 2.15 mm. Results from our study may be used to select a PIT tagging protocol for the endangered grotto sculpin to gain a better understanding of population characteristics.

Materials and Methods

Kick-seining was completed to collect 150 banded sculpin from the Castor River near Marquand, Missouri. After collection, they were transported back to a wet lab, acclimated, and placed in a series of tanks. Our arrangement of tanks consisted of sixty-four 37.9 L glass aquaria in rows of eight. Water quality conditions of pH, turbidity, temperature, and dissolved oxygen were monitored and kept constant throughout the experiment. Banded sculpin were randomly sorted into three groups, and individual fish were placed in a randomly selected aquarium. After fish were placed in their aquariums, there was an acclimation period of one week prior to tagging. Fish were fed chironomids ad libitum at the same time of day, every day during the acclimation period and during the duration of the study.

The three groups of 50 fish each were either tagged with 8.3 × 1.4 mm tags (small tags), tagged with 12.0 × 2.15 mm tags (large tags), or untagged as a control group. Fish in each group were divided into size classes of less than 49 mm in length (juveniles), 50–59 mm (subadults), and 60 or more mm (sexually mature) for the assessment of growth, sizes selected based on previous observations of life stages in grotto sculpin by Adams et al. (2008).

After acclimation, banded sculpin were measured for total length to the nearest millimeter and after tagging, if any, weighed to the nearest 0.001 g (Ruetz III et al., 2006). The 12.0 × 2.15 mm tags were inserted using a 12-gauge needle, while 8.3 × 1.4 mm tags were inserted with a 14-gauge needle. Insertion location of tags was similar to that in the study completed by Ruetz III et al. (2006). Tags were inserted into the body cavity just off the mid-ventral line, anterior of the vent. Needles were inserted at a 45-degree angle and were positioned parallel to the long axis of the body. Once the needle penetrated the musculature, the tag was pushed into the body cavity with the injector (Nielsen, 1992; Ruetz III et al., 2006). Fish were weighed and measured for total length every 7 for 28 days after the tag date (Ruetz III et al., 2006).

Survival percentage of fish group and size class was observed. Average change in weight for fish that survived and

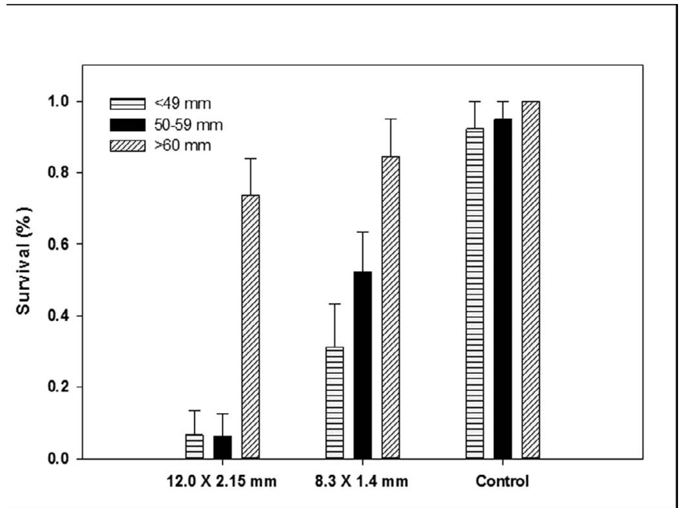

Figure 1. Survival percentage of banded sculpin after 28 days in different size classes within each group (8.3 × 1.4 mm PIT tag, 12.0 × 2.15 mm PIT tag, and control). Lines indicate standard error.

retained their tags throughout the study period was used to assess growth. Casualties were not used in change-in-weight calculations because using fish that expired or dropped their tag during the study could skew growth data. Change in weight was calculated by subtracting the original post-tagging weight of an individual from the weight of the individual at the end of the experiment. Calculated weight change was log transformed, and a one-way ANOVA was used to compare for differences among tag and control groups. All post-hoc comparisons of average change in weight between tag groups were Bonferroni corrected.

A binomial logistic regression analysis was also completed to determine size of individuals that could be successfully tagged. A success was viewed as an individual that survived and retained a tag for the extent of the 28-day study period. A failure was viewed as an individual either dropping its tag or dying at any point in time prior to the completion of the study. These two possibilities were used in conjunction with the initial length of fish within the binomial logistic-regression model to calculate the probability of a successful tagging event at a given length.

Results

Survival percentages for each size class are shown in Figure 1. Among juvenile fish, the lowest survival percentage was in fish tagged with large tags (6.7 %), followed by fish tagged with small tags (31.3 %). The control group exhibited the highest survival for juvenile fish (92.3 %). The control group also had the highest survival percentage for sub-adult fish (95.0%), followed by fish tagged with small tags (52.4 %). The group that had the lowest survival percentage for sub-adult fish was the large-tag group (6.3 %). Finally, for adults

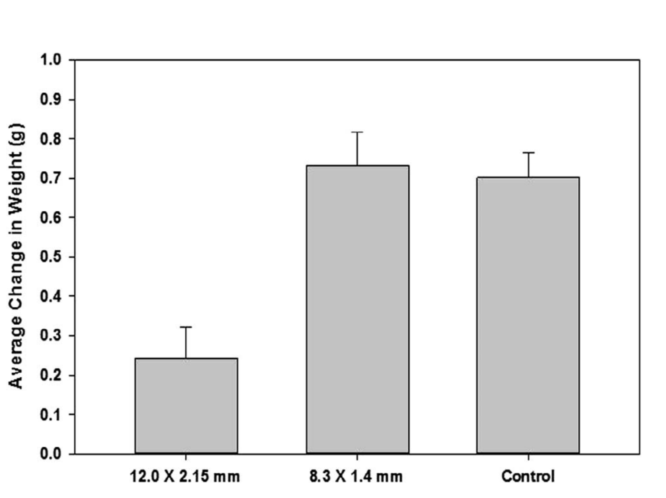

Figure 2. Growth indicated by average change in weight (g) by group (8.3 × 1.4 mm, 12.0 × 2.15 mm, and control). Standard error of the averages indicated.

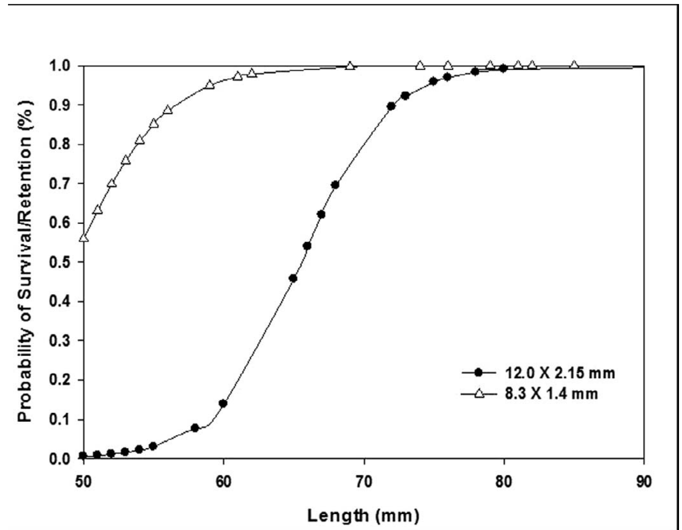

Figure 3. Probability of survival and tag retention calculated with a binomial logistic-regression model for fish tagged with PIT tags (8.3 × 1.4 mm and 12.0 × 2.15 mm tags).

the control group exhibited the highest survival percentage (100%) followed by fish tagged with small tags (84.6 %), and again fish tagged with large tags had the lowest survival percentage (73.7 %).

There was no significant difference in growth between the control (0.7011 ± 0 .0611 g) and small tag groups (0.7334 ± 0.0777 g) ($F = 9.22$; df = 2, 65; $p = 0.0003$). However, the large tag group (0.2432 ± 0.0987 g) was significantly different from both the control and small tag groups. Generally, growth rates of fish within the control group and fish tagged with small tags were higher than growth rates of fish tagged with large tags (Figure 2).

Using the binomial logistic-regression model, the size of fish that can be effectively tagged with each tag size was assessed. The effective level, in this case probability of retention and survival, was set at 95 %. These levels were met for small tags when fish were 60 mm in length or greater (Figure 3). For large tags, a 95 % success rate was attained with fish that were at least 75 mm in length (Figure 3).

Discussion

Our study allowed us to accomplish the objectives of evaluating PIT tag retention and estimating survival and growth of tagged individuals when utilizing two different sizes of PIT tags (8.3 × 1.4 mm and 12.0 × 2.15 mm). Based on results garnered, future studies can utilize the tagging methods outlined in our study on the banded sculpin and other closely related sculpin species, such as the endangered grotto sculpin, that are longer than 60 mm in total length. However, fish less than 60 mm in length should not be tagged, and future research should focus on determining tagging protocol to effectively tag smaller fish.

We assume our findings will translate to field studies, because previous research indicates PIT tagging results are similar between controlled and environmental settings (Tatara, 2009). Therefore, because our tagging techniques were successful in utilizing small tags on fish longer than 60 mm in length, our tagging protocol can be utilized in field studies in relation to both banded and grotto sculpin. By utilizing PIT tagging techniques beneficial ecological information such as spawning habitat and intra-/inter-species interactions can be obtained and used in conjunction with population indices to help direct conservation and restoration efforts for the grotto sculpin. With freshwater sculpin species being widespread throughout the Northern Hemisphere, the potential for obtaining valuable intra- and inter-species ecological interactions in sculpin-occupied streams is also widespread.

We are able to support the premise that utilizing PIT tags can be effectively used to mark small bodied fishes (Gibbons and Andrews, 2004; Skalski et al., 2009; Fuller and McEntire, 2013). Supporting evidence included effectively tagging fish 60 mm and larger when utilizing 8.3 × 1.4 mm tags. The apprehension surrounding tagging small individuals can be alleviated based on our results, especially when using small tags on banded and grotto sculpin longer than 60 mm in total length. Our findings also support the assumption found in other studies that PIT tags do not strongly affect the growth and mortality of small fishes (Prentice et al., 1990; Quartararo and Bell, 1992; Ombredane et al., 1998; McCormick and Smith, 2004). We were able to support this assumption with small tags exhibiting no significant difference in growth in comparison to the control group. We were also able to support the findings of other studies by demonstrating that results vary depending on tag size, tag insertion procedure, species being tagged, and size of the individuals being tagged (Hirt-

Chabbert and Young, 2012; Fuller and McEntire, 2013). Results garnered from our study provide evidence for the effects of PIT tagging small non-salmonid species. More specifically, our study provides insight into PIT tagging two sculpin species, but there is still a need for more research concerning the effects of PIT tagging in other small-bodied fishes.

Although batch marking or individual recognition techniques can be problematic on small fishes, these techniques can be used to gain data required to make good management decisions, especially in regards to conservation and restoration of a species (Ruetz III et al., 2006; Skalski et al., 2009; Tatara, 2009; Fuller and McEntire, 2013). However, PIT tagging small fish is supported by the results found within our study with banded sculpin and likely can be applied to a closely related sculpin species such as the endangered grotto sculpin. Therefore, our tagging procedures likely can be utilized in future mark-recapture studies concerning both banded and grotto sculpin. Such mark-recapture studies can provide a non-lethal way to monitor and assess population characteristics, thus being an effective tool for monitoring endangered species. Specifically, the information that can be provided by mark-recapture studies includes insight into growth, recruitment, and mortality, providing insight into the ecological function of a species which is essential for fisheries conservation and restoration decisions (Gibbons and Andrews, 2004; Ruetz III et al., 2006; Skalski et al., 2009; Hamel et al., 2015; Ruetz III et al., 2015). Mark-recapture studies are an effective tool when evaluating population dynamics and ecological role and can allow researchers the ability to make better restoration decisions concerning grotto sculpin and the cave ecosystems they inhabit.

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