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MANAGEMENT BRIEF

Retention of T-Bar Anchor Tags for Channel Catfish in the Red River of the North

Jonathan J. Spurgeon*
University of Arkansas at Pine Bluff, 1200 North University, Pine Bluff, Arkansas 71601, USA

Mark A. Pegg and Stephen F. Siddons
University of Nebraska–Lincoln, 3310 Holdrege Street, Lincoln, Nebraska 68583, USA

Henry H. Hansen
Department of Biology and Ecology of Fishes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, 12587 Berlin, Germany

Abstract

Tagging fish for mark–recapture studies is a common practice in fisheries science that is used to estimate population parameters. However, biased estimates may result from an incomplete understanding of tag retention. The objective of this study was to assess tag retention for a large-river population of Channel Catfish *Ictalurus punctatus* over a 2,196-d period by using both discrete and instantaneous tag-retention models. A total of 3,827 Channel Catfish were double tagged with T-bar anchor tags in the Red River of the North from 2013 to 2016. The number of tagged Channel Catfish that were recaptured from 2013 to 2019 was 227, with 177 individuals retaining both tags and 50 individuals retaining one tag. Tag retention was estimated at 88% over the study interval by using a discrete tag-retention estimator. An instantaneous tag-retention model suggested that initial tag retention was high, while instantaneous tag shedding was 0.00028 (95% CI = 0.00021 to 0.00038). Based on the instantaneous model, tag retention was predicted as 90% (95% CI = 87% to 93%) at the end of the first year and 54% (95% CI = 44% to 64%) at the end of the study interval. When instantaneous estimates of tag retention are obtained, T-bar anchor tags may be appropriate for studies that evaluate population parameters for Channel Catfish over extended periods.

Understanding the tag-retention process is fundamental to ensure that mark–recapture studies enable accurate estimates of population abundance, survival, growth, and movement (Guy et al. 1996; Pine et al. 2012). If tag retention is low, for instance, negatively biased estimates of population survival may result and lead to unnecessary management actions (Fabrizio et al. 1999). Furthermore, low tag retention can impede analyses by causing low accuracy and precision in the population parameter estimates (i.e., survival and movement) that are generated simultaneously by using advanced statistical methods (Pine et al. 2012). The tag type, location of the tag on a fish, species of fish, environment (e.g., lake or river), and the skill of the tagger are all possible factors that can influence tag retention (Timmons and Howell 1995; Buzby and Deegan 1999; Daugherty and Buckmeier 2009; Pine et al. 2012). Therefore, the estimation of tag retention through field-based or literature-based evaluation is a critical step toward ensuring reliable estimates for population parameters from mark–recapture studies (Pine et al. 2012).

Assessments of Channel Catfish *Ictalurus punctatus* populations in river environments are increasingly needed, as the species has become a popular sport and sustenance fish in many river systems throughout its distribution (Michaletz and Dillard 1999; Bodine et al. 2013). Implementating mark–recapture studies in large-river systems may facilitate the assessment of Channel Catfish populations by providing data that can be used for estimates of the population parameters for this species (Siddons et al. 2017). Tagging Channel Catfish as part of mark–recapture

*Corresponding author: spurgeonj@uapb.edu
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studies has been employed, and different tag types including Carlin danglers, spaghetti tags, T-bar anchor tags, and visual implant tags have been used (Greenland and Bryan 1974; Timmons and Howell 1995; Buckmeier and Irwin 2000). However, many of the tag-retention studies have been conducted under controlled settings, whereas few studies have reported conclusive retention rates for anchor tags in Channel Catfish that have been at large for extended periods. Our objective was to estimate the tag-retention probability for T-bar anchor tags in a large-river population of Channel Catfish over a 2,196-d (~6 years) period.

METHODS

Channel Catfish were captured with baited hoop nets and with rod-and-reel gear from May to October 2013–2016 from the Red River of the North (hereafter, "Red River") in Manitoba, Canada (the lower 233 km of the river). Each Channel Catfish >250 mm TL received two T-bar anchor tags (Floy 68-B or 67-F). The tag lengths were 65 mm (T-length = 10 mm) for the small tags (68-B) and 90 mm (T-length = 16 mm) for the large tags (67-F). The 68-B tag was used for individuals < 500 mm TL to minimize the influence of the tag on fish behavior. Furthermore, small tags were assumed to be incapable of anchoring properly on catfish >500 mm TL due to the spacing between their pterygiophores. The tags were inserted through the pterygiophores and were staggered on opposing sides of the dorsal fin (Figure 1). Opposing sides were chosen to reduce potential wear near the insertion point that may influence the retention of the second tag if the tags are inserted too closely together (Pine et al. 2012). Each tag was uniquely labeled with a serial number on one side and a toll-free phone number on the opposite side for anglers to report tagged fish.

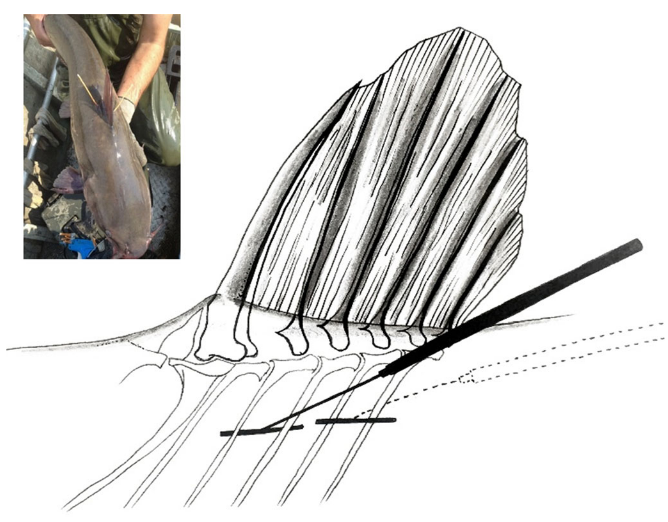

FIGURE 1. Tagging locations of staggered T-bar anchor tags across the dorsal musculature along the dorsal fin in Channel Catfish. The T-bar tags were inserted across the pterygiophores. [Color figure can be viewed at afsjournals.org]

Recaptured Channel Catfish were reported by research crews and recreational anglers in the Red River and in Lake Winnipeg. Commercial fishers in Lake Winnipeg also contributed information from Channel Catfish that were captured in commercial fishing gears. The individuals that returned tags were asked for tag numbers and whether both tags were still present in the fish when it was captured.

Tag retention was estimated by using both a discrete and an instantaneous model (McCormick and Meyer 2018). The discrete model estimated the probability of tag retention (P_d) by using the data for the recaptures, pooled over the course of the study, by using

$$P_d = 1 - \frac{N_A}{N_A + 2N_{AA}},$$

where N_A is the number of individuals that were recaptured with a single tag and N_{AA} is the number of individuals that were recaptured with both tags (Wetherall 1982; McCormick and Meyer 2018). Additionally, we used the discrete estimator to examine year-specific estimates of tag retention, using only the data that were collected (i.e., fish that were reported with 1 or 2 tags) during a given year.

The instantaneous model was used to estimate the probability of retaining a single tag (Q) following a period at large (t) as follows:

$$Q(t) = \alpha e^{-Lt},$$

where α is the immediate tag retention and L is the instantaneous rate of tag shedding (Barrowman and Myers 1996; Vandergoot et al. 2012; McCormick and Meyer 2018). We assessed a second model from McCormick and Meyer (2018) that assumed that initial tag retention was 100% (i.e., α = 1). The probability that an individual would retain both tags was calculated with the equation

$$P_{AA}^{AA} = Q(t)^2,$$

and the probability that an individual would retain one tag was given by

$$P_A^{AA} = 2Q(t)[1 - Q(t)].$$

The probability of observing either outcome (i.e., one or two tags upon recapture) was given as the probability of observing either a single- or double-tagged individual following a given amount of time divided by the sum of both observing a single- or double-tagged individual following a given amount of time (Gaertner and Hallier 2015; McCormick and Meyer 2018). The model parameters α and L were estimated by using maximum likelihood through minimizing the negative of the log-likelihood function (l) conditioned on the observed periods at large by using

$$l = \sum_{j=1}^{N_{AA}} \log_e \frac{Q(t_j)^2}{Q(t_j)^2 + 2Q(t_j)[1 - Q(t_j)]} + \sum_{k=1}^{N_A} \log_e \frac{2Q(t_k)[1 - Q(t_k)]}{Q(t_k)^2 + 2Q(t_k)[1 - Q(t_k)]},$$

where t_j is the period at large for individuals that were recaptured with both tags and t_k is the period at large for individuals that were recaptured with a single tag (Barrowman and Myers 1996; McCormick and Meyer 2018). We did not include models where tag retention varied with time, as we did not expect tag retention to improve or degrade following the initial retention period. Additionally, studies have suggested that time-varying models may not necessarily improve model accuracy (Gaertner and Hallier 2015). Support for time-varying models was suggested by McCormick and Meyer (2018), but the model rankings were similar between the two model types (time-varying and time constant) and some of the support for the time-varying models was suggested to be due to variation in the data and not necessarily a reflection of the tag-retention process (McCormick and Meyer 2018). The Akaike information criterion corrected for small sample sizes (AIC_c) was used to assess model fit between the two instantaneous models. All of the statistical analyses were done in Program R (R Core Team 2018). The likelihood function was minimized by using the mle2() function in the bbmle package (Bolker 2017). The standard errors of the parameters were estimated by using the confint() function in the bbmle package (Bolker 2017).

RESULTS

A total of 3,827 Channel Catfish (250–995 mm TL) were double tagged. We confirmed that 227 individuals were recaptured from 2013 to 2019 (Table 1). The two tag types were combined to estimate tag retention by using both the discrete and instantaneous models. A total of 177 (78%) individuals were recaptured with both tags and 50 (22%) individuals were recaptured with a single tag. Time at large ranged from 0 to 2,196 d (~6 years). Tag retention was estimated at 88% with the discrete model, which used pooled data across the entire study period. Tag retention was 96% after 1 year, 83% after 2 years, 78% after 3 years, 82% after 4 years, and 59% years after 5 years, based on the results from the discrete estimator that were calculated with data that were collected only during those years. Limited recaptures (i.e., $n = 1$) of individuals that contained single or double tags prevented the estimation of tag retention by using the discrete estimator beyond 1,825 d. The instantaneous model, where initial tag retention was assumed to be 100% (α = 1), was the most supported model ($AIC_c = 205.85$ versus 293.86). The tag-shedding parameter estimate was $L = 0.00028$ (95% CI = 0.00021 to 0.00038). Tag retention was predicted as 90% (95% CI = 87% to 93%) at the end of the first year and 54% (95% CI = 44% to 64%) at the end of the study interval based on the instantaneous tag retention model (Figure 2).

DISCUSSION

The estimated first-year tag retention for Channel Catfish in the Red River (90% based on the instantaneous model) was greater than some previously reported anchor-tag retention rates for catfish. Buckmeier and Irwin (2000) found 71% retention after 270 d when Floy FD-68B anchor tags were used on Channel Catfish (280–379 mm TL). Furthermore, tag retention in Blue Catfish *Ictalurus furcatus* (364–1005 mm TL) was 76% after 6 months (Bodine and Fleming 2014), and tag retention was approximately 50% after 250 d for Channel Catfish and Blue Catfish (Timmons and Howell 1995). Our results suggest that after approximately 6 years (2,196 d), a Channel Catfish population of tagged individuals may retain approximately 54% of the initial tags. Variation in retention rates across studies may be due to tag sizes, species, environmental variables, and the experience of taggers (Pine et al. 2012). Furthermore, model type (i.e., discrete versus instantaneous) may influence tag retention estimates. For example, the instantaneous model provided a lower probability of retention at the completion of the study period

TABLE 1. The number of initially double-tagged Channel Catfish with double (AA) or single (A) tags at recapture in the Red River of the North, grouped by days at large. The exact time at large (in days) was used in all of the modeling.

Tag combination	Days at large					
	0–365	366–730	731–1,095	1,096–1,460	1,461–1,825	>1,826
AA	96	43	18	14	5	1
A	9	18	10	6	7	0

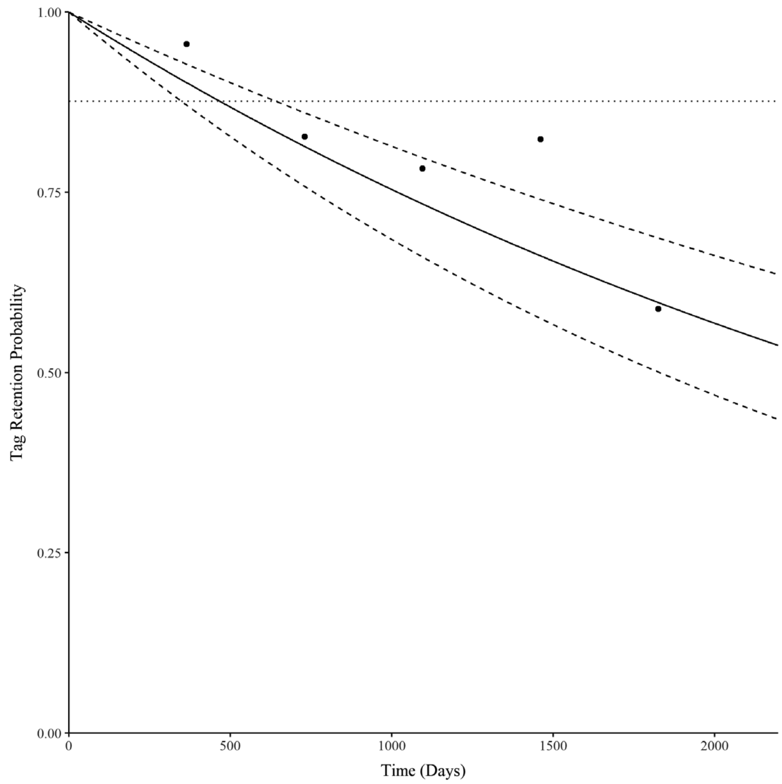

FIGURE 2. Probability of tag retention through time (in days) for Channel Catfish in the Red River. The solid black line represents the predicted tag retention, and the dashed lines represent the 95% confidence interval for the instantaneous tag retention model (based on AIC_c), where 100% initial tag retention was assumed (i.e., $\alpha = 1$; McCormick and Meyer 2018). The points are the discrete point estimates through time. The dotted line represents the pooled (across all years) discrete estimate of tag retention.

than did the discrete model that used the pooled data. The length of time that individuals are at large can influence the biological relevance of the discrete estimator (McCormick and Meyer 2018). Individuals in this study were at large for approximately 6 years, so the instantaneous model may describe the tag retention process over that length of time more accurately. For example, the estimates from the discrete and instantaneous methods were similar after the first year of the study but quickly diverged thereafter. The discrete model approach may be an attractive alternative to instantaneous models due to reduced quantitative demands, but as was shown in this study pooling data over long periods may not accurately reflect the tag retention process and may produce biased estimates.

Anchor tags appeared to be a useful tag option for mark–recapture studies that involve Channel Catfish that occur over extended periods. Our study evaluated tag retention over the course of >2,000 d at large for some individuals, which exceeds previous tag evaluation efforts. However, we were unable to estimate tag retention for the two tag sizes independently due to too few recaptures. Tag retention is predicated on proper tagging to ensure that the tag is anchored correctly, and future work should consider the influence of tag size on tag retention (Guy et al. 1996; Sprankle et al. 1996). Similarly, changes in body size throughout the study period may also need to be accounted for in tag selection (Pine et al. 2012). We noted that anglers misidentified double-tagged catfish on occasion because a single tag was positioned through the dorsal musculature and was sticking out of both sides. Thus, care should be taken in future studies to properly question anglers that report tagged fish. Future research to evaluate size-dependent influences on anchor-tag retention may be warranted. Ultimately, our study further affirms previous work in that the consideration of tag retention is needed when mark–recapture studies are used to estimate population parameters. The decision between using a discrete or instantaneous model will depend on the study objectives (e.g., predictions between periods can only be obtained with instantaneous models) and the length of time over which recaptures are acquired (e.g., pooling over long periods may bias tag retention estimates). Instantaneous tag loss models are more suitable for the assessment of tag retention in long-term studies because the discrete models may not accurately reflect the tag retention process over long periods. Additionally, discrete estimates among years are dependent on obtaining enough samples each year of both single- and double-tagged individuals.

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ORCID

Jonathan J. Spurgeon https://orcid.org/0000-0002-6888-5867

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