14(2): 001-007 (2020)

Journal of FisheriesSciences.com

E-ISSN 1307-234X

Research Article

Short Term Survival and Tag Retention of Gizzard Shad Implanted with Dummy Transmitters

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Received: 06.04.2020 / Accepted: 08.06.2020 / Published online: 15.06.2020

Abstract: Little is known about Gizzard Shad *Dorosoma cepedianum* life history and habitat use near the far northern edge of their native range. In 2016, the South Dakota Department of Game, Fish, and Parks aspired to implement an acoustic telemetry study to take a more in-depth look at Gizzard Shad movements and habitat use. However, adult Gizzard Shad have never been surgically implanted with telemetry tags. The objectives of this study were to determine if Gizzard Shad can survive surgery and handling, assess short-term survival and tag retention after surgery and determine what factors affect survival of tagged adult Gizzard Shad. Forty adult Gizzard Shad were surgically implanted with VemcoV13 dummy tags and 40 control fish were placed in a floating net pen. Survival of control fish averaged 90% and survival of tagged fish averaged 88% during the study. With a relatively small sample size, we failed to detect a significant difference in survival of control or tagged fish. Short-term tag retention was high, with only one fish expelling a tag during the study. Survival of tagged Gizzard Shad increased with increasing water temperature at time of capture. Our results suggest Gizzard Shad appear suitable for surgical implantation of telemetry tags. The influence of warmer water temperatures on survival rates of Gizzard Shad indicates the importance of considering life history information when designing and implementing future tagging studies.

Keywords: Gizzard shad; *Dorosoma cepedianum*; *Micropterus dolomieu*

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Journal abbreviation: **J FisheriesSciences.com**

Introduction

Gizzard Shad *Dorosoma cepedianum* in South Dakota are near the northwestern edge of their native range and often experience high over-winter mortality (Ward et al. 2006; Wuellner et al. 2008;VanDeHey et al. 2012). However, in Lake Sharpe in central South Dakota, Gizzard Shad persist through harsh winters (Graeb 2006). The persistence of Gizzard Shad in Lake Sharpe is critical as they serve as the primary prey fish species in this high-profile, recreationally important Walleye *Sander vitreus* and Smallmouth Bass *Micropterus dolomieu* fishery (Wuellner et al. 2010). Lake Sharpe also serves as the primary source population for Gizzard Shad stockings across North and South Dakota (Ward et al. 2006; Wuellner et al. 2008; Fincel et al. 2017). Despite the critical food web role of Gizzard Shad to Lake Sharpe and other upper midwest reservoirs (Bethke et al. 2012; Fincel et al. 2014), little is known about this population. Only recently, otolith microchemistry was used to evaluate natal habitats of age-0 Gizzard Shad in Lake Sharpe (Radigan et. al 2018). However, there is no information regarding adult Gizzard Shad movements and winter habitat use. This is particularly important as it could reveal key locations for the continued over winter survival of Gizzard Shad such as warm-water seeps or natural springs.

The use of acoustic telemetry systems in fisheries research has dramatically increasedover the last two decades (Cooke et al. 2011; Heupel and Webber 2012). Once considered novel technology, acoustic telemetry systems have rapidly evolved into a robust tool for documenting all facets of fish behavior including spawn timing, survival, migrations, movements, and broad or fine-scale habitat use (Cooke et al. 2011; Heupel and Webber 2012; Hockersmith and Beeman 2012). Moreover, with advances in passive monitoring systems, data can be collected in real-timeor catalogued for continuous monitoring allowing for complete diel coverage of species movements with little effort. Thus,fisheries scientists are now able to collect in-depth information from sensitive life stages and small-bodied fishes or infrequentuse of habitats that are difficult to document (Heupel and Webber 2012).

One drawback to using acoustic telemetry systems is that performing surgery and implanting a foreign object into the body cavity of a fish can impose significant physiological and behavioral changes, predisposing an individual to increased predation and infection risks leading to mortality or study bias (Bridger and Booth 2003; Close et al. 2003; Cooke et al. 2011). One of the principal assumptions of tagging studies is that tagged individuals exhibit the same behavior and mortality rates of untagged individuals and that none of the individuals experience tag loss (Neely et al. 2009; Gardner et al. 2015). Thus, prior to using acoustic telemetry systems, researchers may perform a set of controlled surgical studies to determine the suitability of telemetry for a given species. Across species, tagging success and tag retention appear to vary greatly (Mellas and Haynes 1985; O'Connor et al. 2009; Koehn 2012); therefore, it is important to examine these factors prior to implementing acoustic telemetry studies.

While use ofacoustic telemetry systems is warranted, there is a need to evaluateadult Gizzard Shad response to surgery. Our objectives were to: 1). determine adult Gizzard Shad survival rates based on capture, surgery methods, and handling, 2.) assess short-term survival of adult Gizzard Shad and tag retention 3- or 5-dayspost-surgery and 3.) determine if water temperature at time of capture, changes in water temperature, and/or surgery duration affect survival of tagged adult Gizzard Shad.

Methods

Adult Gizzard Shad (length range: 389-577 mm total length [TL]) were collected usingtargeted boat electrofishing (Smith-Root 5.0 GPP, Pulsed Direct Current; 60 pulses/sec, 7-9 amps) in Hipple Lake, a backwater embayment of Lake Sharpe, South Dakota **(Figure 1)**, during April and May of 2014 and 2015. A maximum of five fish were collected during each electrofishing passto reduce crowding in boat live well. Adult Gizzard Shad were randomly assigned to either the control group (n=20 per year; 40 total)or surgery group (n=20 per year; 40 total). A total of five experimental groups were assessed; two in 2014 and three in 2015. Three of the five groups included n=10 surgery and n=10 control fish in the same net pen, and two of the groups included n=5 surgery and n=5 control fish in the same net pen. Discrepancy in sample size between experimental groups was due to low catch rates during electrofishing events in 2015. After capture, fish assigned to the control group were measured (TL; mm) and placed in a floating net pen (4 m x

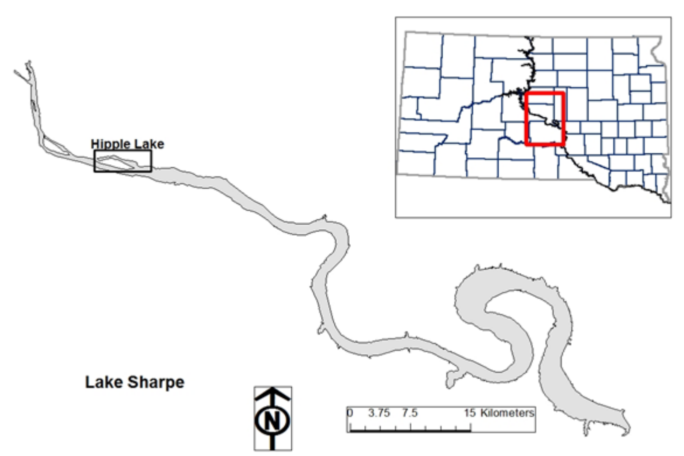

Figure 1: Map of Hipple Lake, a backwater embayment in Lake Sharpe, South Dakota where adult Gizzard Shad were collected by boat electrofishing, implanted with telemetry tags and kept in a net pen during April and May of 2014 and 2015.

4 m x 2 m) made of black nylon mesh, a polyvinyl chloride pipe frame and foam buoys. Fish assigned to the surgery group were measured, immobilized using electroanesthesia (Smith-Root 5.0 GPP, Pulsed Direct Current; 60 pulses/sec, 7-9 amps; Beaumont 2016), and surgically implanted with a Vemco (Halifax, Nova Scotia, Canada) V13 dummy tag (36 mm length x13 mm diameter; 11 g in air) and placed in the same floating net pen as control fish.

All tagged Gizzard Shad weighed more than the suggested minimum weight (550 g) with a tag burden of≤ 2% (Winter 1996). Dummy tags and surgical instruments were sterilized using povidone iodine (Betadine, Purdue Products L.P., Stamford, CT) prior to surgery. Tags were inserted into the abdominal cavity through a lateral incision approximately 4 cm long, located posterior to the left pectoral fin. Due to the large size of the fish, 5-10 scales needed to be removed from the incision site to allow for penetration of both the scalpel and suture needle. Due to the size of the tag and the lateral location of the incision 2-3 ribs were cut to allow for insertion of the tag. The incision was closed with three interrupted monofilament, non-absorbable sutures. No antibiotics were applied after the surgery. We recorded surgery duration (s), water temperature (°C) at time of capture, and water temperature (°C) in the net pen at the end of each trial period. Survival of control and surgery fish, and retention of dummy tags was assessed three days (2014) or five days (2015) post-surgery.

We used an analysis of variance (ANOVA) to test for differences in length of fish in 2014 and 2015 (α=0.05). Survival rate (%) was transformed using the arcsine transformation, and an ANOVA was used to test for differences in survival between treatment groups for each year (α=0.05). Logistic regression was used to assess effects of surgery duration, water temperature (measured as both the temperature at the time of capture and the difference in temperature between capture and the final temperature in the holding pen), holding time (d) and fish length on survival. We used a significance level of α=0.05 for variable inclusion in the logistic regression model. All analyses were performed using R version 3.6.2 (R Core Team 2019).

Results

Average length of adult Gizzard Shad in the control group was similar between years, 505 ± 7 mm in 2014 and 486 ± 7 mm in 2015 (*P*=0.1. *F*=4.1). Average length of Gizzard Shad in the surgery group was greater in 2014 (498 ± 5 mm) than in 2015 (474 ± 8 mm; *P*=0.01, *F*=4.1). Surgery duration averaged 201 ± 8 s in 2014 and 148 ± 8 s in 2015. Survival was relatively high for both the control (range 85-95% survival) and the surgery group (range 90-95%survival) during 2014 and 2015 trials (**Figure 2**). Short-term retention of dummy tags was also high; 100% in 2014 and 95% in 2015(only one fish expelled a dummy tag in 2015). There was no difference between overall survival of control fish (mean 88%) and surgery fish (mean 87%; *P*=0.7; *F*=4.96). There was also no difference in survival within treatment groups, between years (control *P*=0.3, *F*=7.7; surgery *P*=0.1, *F*=7.7).

Water temperature (at the time of capture and as the difference in temperature between time of capture and final net-pen temperature) was the only significant variable in the logistic regression models (*P*=0.02 for both metrics). Water temperature at time of capture averaged 14.8 ± 0.6 °C during the 2014 trials and 17.7 ± 0.4 °C during the 2015 trials (**Figure 3**). Water temperature in the net pen at the end of trials averaged 15.4 ± 0.6°C in 2014 and 18.5

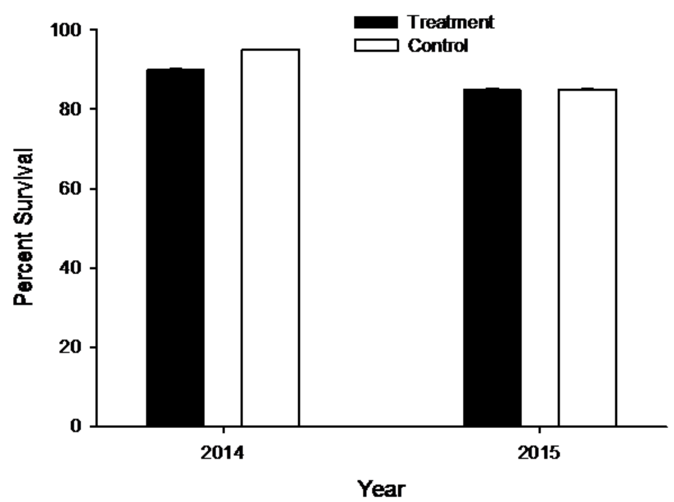

Figure 2: Survival of adult Gizzard Shad surgically implanted with Vemco V13 dummy transmitters (black bars) and control fish (white bars) during 2014 and 2015 and held in a net pen in Hipple Lake, South Dakota.

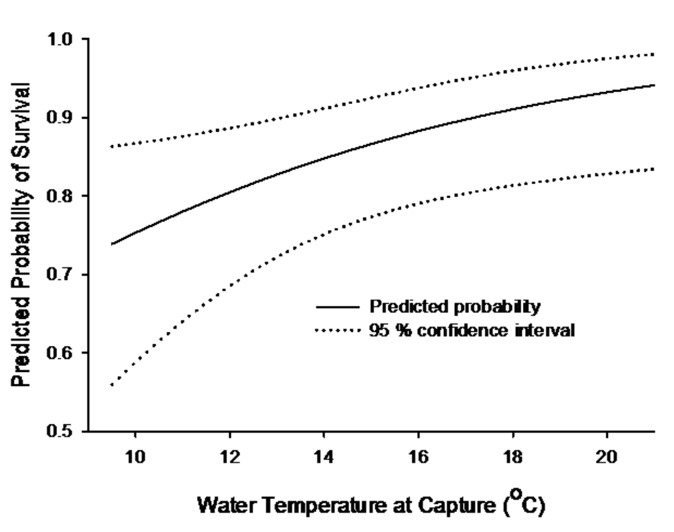

Figure 3: Predicted odds (solid black line) of survival of adult Gizzard Shad versus water temperature at time of capture (°C) in Hipple Lake, South Dakota. Black dashed lines represent 95% confidence intervals.

± 0.4 °C in 2015 (**Figure 3**). For every 1°C increase in water temperature at time of capture, the odds of survival increased by a factor of 1.2.

Discussion

Gizzard Shad appear suitable for tagging studies, as short-term survivalafter surgical implantation was high (average > 85% for tagged fish). Most tag implantation studies report survival rates from 75-99% (Jepsen et al. 2001; Holland et al. 2006; Neely et al. 2009). Other studies assessing the impacts of surgically implanted tags on fishes found survival rates as low as 60% (Lacroix et al. 2004; Hall et al. 2009) to as high as 100% (Martinelli et al. 1998;Snobl et al. 2015). Surgery duration in our study waswithin the range of 180-360 s reported in other studies (Jacobsen et al. 2002;Hall et al. 2009;Gardner et al. 2015). Although no literature exists on surgical procedures for Gizzard Shad,our study produced results similar to established protocols used for other species. Most previous work implanting telemetry tags in fishes have focused on salmonids, cyprinids, ictalurids, percids, and centrarchids (Cooke et al. 2011). This study contributes to telemetry methodologies by using known surgery techniques on a newly studied fish species.

Mortality of control fish during the study indicates a need to assess current capture and handling procedures. In a review of surgical implantation methods, Mulcahy (2003) suggested that the capture event is one of the most stressful parts of transmitter implantation. Prey-species appear to experience more acute stress during handling and tagging than predatory species (Jepsen et al. 2002). Severalauthors report mortality of control fish during their respective tagging study, which indicates that the capture, and subsequent handling and holding of fish is inherently stressful (Cooke, et al. 2003; Neely et al. 2009; Hall et al. 2009). For example, Gizzard Shad experienced a 6.3 magnitude increase in plasma corticosteroid concentrations after being transported in a hauling tank for two h after capture (Davis and Parker 1986). Similarly, Chinook Salmon *Oncorhynchus tshawytscha* that were anesthetized and handled (but not surgically implanted with telemetry tags) had a significant increase in plasma cortisol levels for 4-24 hafter handling (Jepsen et al. 2001). Gilthead Sea Bream *Sparus aurata* and Tilapia *Oreochromis mossambicus* experienced elevated cortisol levels when subjected to confinement and crowding (Sunyer et al. 1995; Vijayan et al. 1997). The effects of multiple stressors (e.g. capture, handling, and confinement) can be cumulative, and reduce a fish's ability to recover from those stressors (Barton et al. 1986; Barton 2002). Chronically elevated levels of stress hormones can result in immunosuppression and possibly mortality (Sunyer et al. 1995;Kelsch and Shields 1996; Barton 2002). Even with the presence of anesthesia to immobilize fish, handling and confinement is stressful, and acute stress can eventually lead to mortality.

This study documented low transmitter expulsion rates up to five days post-surgery. Tag expulsion rates appear to vary with species (O'Connor et al. 2009; Koehn 2012). Tag expulsion was 59% in Rainbow Trout *Oncorhynchus mykiss* after 42-175 d (Chisholm and Hubert 1985), 71% in Channel Catfish*Ictalurus punctatus* after 112 d (Summerfelt and Mosier 1984) and 50-90% after 362 d inCommon Carp *Cyprinus carpio* implanted with dummy tags (Daniel et al. 2009). However, expulsion was 0% after 47 d in wild-caught Rainbow Trout (Martin et al. 1995), 0% after 54 d and 13.2% after 42 d in juvenile Chinook Salmon (Adams et al. 1998; Hall et al. 2009, respectively). Tag expulsion rates can also be related to surgical experience and procedures, tag size and water temperature (Cooke et al. 2003). Expulsion rates were generally higher when fish selected for surgery began approaching or exceeding the 2% guideline (Summerfelt and Mosier 1984; Lacroix et al. 2004; Jepsen et al. 2008). Bluegill*Lepomismacrochirus* and Rainbow Trout implanted with telemetry tags had higher expulsion rates at warmer water temperatures (Knights and Lasee 1996; Bunnell and Isley 1999). Tag coating also appears to influence tag expulsion (Chisholm and Hubert 1985; Helm and Tyus 1992) as well as suture type (Jepsen et al. 2008). Due to the low expulsion rate in this study (2.5%), the authors believe the tagging method (non-absorbable suture material and three interrupted suture pattern)is adequate for implanting adult Gizzard Shad with telemetry tags. When handling and tagging laterally compressed fish (such as Gizzard Shad), considering body morphology may be more important than just tag: body weight ratios (Jepsen et al. 2002). Gardner et al. (2015) implanted Common Bream *Abramisbrama* (440-522 mm FL; similar to sizes of Gizzard Shad in this study) with Vemco V13 transmitters (the same used in this study) and had high survival and minimal tagging effects after release back. Common Bream and Gizzard Shad are morphologically similar (laterally compressed, narrow body cavity and a hard ventral keel), which makes them difficult to implant tags, as evidenced by the removal of scales, cutting of ribs and the large incision size (~4 cm) used in this study and as described in Gardner et al. (2015). Despite the difficulty of implanting tags in the narrow body cavity of Gizzard Shad, this species appears to be hardy enough to withstand the surgical procedure.

Survival of tagged adult Gizzard Shad increased with increasing water temperature. Some authors report higher mortality and greater risk of infection when tagged fish were released into warm water (Walsh et al. 2000; Økland et al. 2001; Cooke et al. 2003). However, Jepsen et al. (2002) reports that tagging European Perch *Percafluviatilis* and Roach *Rutilusrutilus* at temperatures 20°C and greater caused no adverse effects compared to fish tagged at lower temperatures. Hybrid Striped Bass *Moronesaxatilis*× *M. chrysops* surgically implanted with telemetry tags had faster incision closure at warmer temperatures (96% after 7 days) versus slower incision closure at low temperatures (78% after 7 days; Walsh et al. 2000). Despite faster healing, hybrid Striped Bass held at higher temperatures had higher cumulative mortality than fish held at lower temperatures (Walsh et al. 2000). While higher temperatures may promote faster healing rates (Anderson and Roberts 1975), there appears to be a trade off with higher mortality rates in some species (Knights and Lasee 1996; Bunnell and Isley 1999; Walsh et al. 2000). In the present study, higher water temperatures lead to lower mortality in Gizzard Shad. We did not assess healing rates during our study, so the exact mechanism behind the influence of water temperature cannot be determined. There may be a need for future research on healing rates to determine long-term tag retention for studies with a longer duration. Tagging of tropical fish species at temperatures lower than their optimal range cause higher mortality rates than tagging fish at warmer water temperatures (Jepsen et al. 2002). Gizzard Shad are a temperate speciesand exhibit reduced survival and reproduction output in colder temperatures (Wuellner et al. 2008; Fetzer et al. 2011; Greiner et al. 2017).

Conclusion

The authors suggest tagging Gizzard Shad in water temperatures above 10°C, with optimal tagging temperatures between 17-21°C, based on the results of the logistic regression model. The influence of warmer water temperatures on mortality rates in combination with the optimal temperature regime of Gizzard Shad indicate the importance of considering life history information when designing and implementing tagging studies.

Acknowledgements

Federal Aid in Sportfish Restoration provided funding for this project. We thank the South Dakota Department of Game, Fish, and Parks Ft. Pierre District Office fisheries staff and Greg Simpson for assistance with surgeries and data collection.

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