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Best Practices for Surgically Implanting Acoustic Transmitters in Spotted Seatrout

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NOTE

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Abstract

Technological advances have made acoustic tracking of fish an effective means to collect unprecedented migration data. However, one must ensure that fish survive the surgical implantation and retain transmitters, and that their health and behavior are not adversely affected. We performed a laboratory study to examine the most effective surgery technique and suture material for implanting acoustic transmitters into Spotted Seatrout *Cynoscion nebulosus*. Six treatment groups were used to investigate two ventral incision locations (midline and off-midline) and three suture materials (braid, monofilament, and staples). Overall survival was high for all fish undergoing surgery (75% for surgical controls, and 74% for surgically implanted fish), suggesting that acoustic transmitter implantation can be very successful for Spotted Seatrout. However, female fish had significantly higher survival (85.7%) than male fish (41.2%). Surgery time ranged from 73 to 270 s, and our results suggest that for every second that the surgery time was reduced the odds of increasing survival are 1.5%. Moreover, the surgery process versus tagging material or incision location is the primary cause of mortality. Overall, there was no one treatment that showed distinct differences in survival and transmitter retention; however, for future telemetry studies using Vemco V13 transmitters with Spotted Seatrout, we recommend researchers (1) target fish greater than 425 mm TL, (2) minimize surgery time (preferably 160 s or less), and (3) use an off-midline incision placement closed with two sutures using braid suture material. These techniques will help ensure successful field acoustic tracking studies by increasing the likelihood of Spotted Seatrout survival and transmitter retention. Finally, these methods have applicability to other fishes, particularly Sciaenids, with high potential for success.

One of the most effective ways to identify movement patterns of fish is through the use of acoustic tracking technology. Passive acoustic ultrasonic telemetry employs an array of stationary receivers to detect signals from fish affixed with uniquely coded transmitters. In addition to movement patterns, this method can identify habitat use and residency times at the landscape-scale, estimate mortality, and provide a host of other useful information. Acoustic telemetry can provide more refined tagging and movement data (including continuous movement patterns) at a much higher resolution and does not rely on angler tag returns. However, it is imperative to ensure that test subjects survive the surgical implantation process and retain transmitters throughout the battery life, and that fish health and behavior is not compromised (Bridger and Booth 2003; Cooke and Wagner 2004).

This study was designed to investigate several surgical methods for implanting acoustic transmitters in Spotted Seatrout *Cynoscion nebulosus*, an important precursor study to longer-term telemetry investigations. The Spotted Seatrout is

an estuarine-dependent Sciaenid that is one of the most important recreational fisheries in the Gulf of Mexico (Kostecki 1984; Pattillo et al. 1997; Bortone 2003; Stunz and Mckee 2006). This species is an important economic resource in Texas, with an estimated annual impact valued over US$2 billion (NOAA 2008). In Texas, the Spotted Seatrout fishery has been regulated since 1978 through minimum size and bag limits (Hegen et al. 1987). Additional information about Spotted Seatrout movement collected through telemetry studies can provide critical information about habitat use patterns to better manage this important fishery.

Acoustic transmitters may be attached externally, inserted intragastrically, or surgically implanted into the peritoneal cavity (Bridger and Booth 2003). Surgical implantation decreases drag and transmitter loss (Bridger and Booth 2003; Harms 2005) and is considered more appropriate for long-term tracking studies (Adams et al. 1998; Jepsen et al. 2002). The typical process involves a small ventral incision, transmitter insertion, and closure (Harms 2005). However, surgical procedures increase handling time, infection risk, and physiological stressors (Jepsen et al. 2001; Bridger and Booth 2003; Hall et al. 2009), and may influence behavior and movement (Wagner and Cooke 2005). Nonetheless, long-term effects of surgical implantation on survival, growth, behavior, and physiology of fish are minimal (Bridger and Booth 2003). Hall et al. (2009) reported that mortality in Chinook Salmon *Oncorhynchus tshawytscha* that underwent surgical procedures with or without transmitter implantation was due primarily to surgery alone. Additionally, since tagging is often conducted in the field, surgical techniques must be simple and efficient to ensure stressors are kept to a minimum (Jepsen et al. 2002).

The most appropriate surgical methods and materials are often variable among species and can change based on study objectives. Typical incision placement is between the pelvic girdle and anus on the ventral midline (linea alba) or lateral to the midline (Wagner and Stevens 2000), and can vary by species and fish size (Bridger and Booth 2003). For example, Wagner and Stevens (2000) found no difference in the amount of inflammation between midline and off-midline incision locations in Rainbow Trout *O. mykiss*. However, unlike the Rainbow Trout, male Spotted Seatrout have well-developed sonic muscles running laterally along the ventral wall of the peritoneal cavity. Damaging these muscles could potentially influence the reproductive capabilities of male Spotted Seatrout, impact healing and survival of surgically implanted Spotted Seatrout, or both. However, successful acoustic telemetry studies have been conducted with Spotted Seatrout using an off-midline incision (Callihan et al. 2013).

Suture materials for incision closure is often a personal preference; however, suture selection should consider the tissue reactivity and healing time (Harms and Lewbart 2000). Commonly used suture materials include braided suture and monofilament suture, though some researchers prefer surgical staples. Braided suture has the benefit of relative ease of tying

and adequate strength (Jepsen et al. 2002), but has wicking properties that provide a potential transport pathway for bacteria to travel into the peritoneal cavity (Wildgoose 2000; Harms 2005), which could potentially increase the risk of infection. In addition, braided suture has been documented to irritate skin surrounding needle punctures (Wagner et al. 2000; Jepsen et al. 2002) and to provide a surface for algal attachment, potentially creating extra drag and promoting grazing activity by other fishes (Thoreau and Baras 1997; Jepsen et al. 2002). Monofilament suture with swaged-on needles may be more difficult to manipulate but minimizes tissue damage and prevents bacterial ingress through capillary effect (Wildgoose 2000; Harms 2005). Thus, monofilament suture may be more appropriate than braided suture to minimize bacterial intrusion (Harms 2005). Suture that is designed to be rapidly absorbed in mammalian tissue exhibits long-term retention in fish (Harms and Lewbart 2000) and is not recommended. Thoreau and Baras (1997) have reported that incisions closed with polyamide monofilament heal faster than braided silk or plain catgut suture in Blue Tilapia *Oreochromis aureus*. Use of staples can dramatically decrease handling time, potentially reducing mortality in species that are easily stressed (Mulford 1984). However, the relative delicate nature of fish skin can be unfavorable for consistent staple placement, resulting in increased mortality and transmitter loss (Harms and Lewbart 2000; Mulcahy 2003; Harms 2005).

Surgical techniques are species specific, and there is a need to develop optimal surgical procedures in a controlled setting prior to conducting experiments in the field (Moore et al. 1990; Bridger and Booth 2003; Fabrizio and Pessutti 2007). A direct investigation of effective surgical techniques to implant transmitters in Spotted Seatrout has not been published in primary literature; thus, the primary goal of this study was to test the null hypothesis that incision location and suture material has no effect on surgical survival of Spotted Seatrout or retention of peritoneal-implanted acoustic transmitters.

METHODS

Seventy Spotted Seatrout were collected via hook and line in two nearby Texas bays: Corpus Christi Bay and Aransas Bay. Spotted Seatrout greater than 350 mm TL were targeted to follow estimated transmitter : body mass ratio guidelines that recommend transmitter weight should not exceed 2% of body weight (Winter 1992; Jepsen et al. 2002; Bradshaw 2006). Additionally, preliminary trials conducted on smaller Spotted Seatrout (<350 mm TL) showed very high mortality when transmitter : body mass ratio approached 3% compared with a relatively low mortality of larger specimens. While maintaining a large size range of fish, this study also included numerous relatively small fish to better estimate the smallest size fish that would survive transmitter implantation. Immediately after collection, fish were temporarily held in 416-L oxygenated holding tanks and transported to the Texas Parks and

Wildlife (TPWD) Coastal Conservation Association Marine Development Center (TPWD-MDC), Corpus Christi, Texas. Experimental animals were held in 12,000-L circular fiberglass tanks (3.7 × 1.5 m) at TPWD-MDC and fed a mixture of dead shrimp and squid to satiation three times weekly. Fish were acclimated for a minimum of 1 week before any experimental procedures were conducted to monitor for any mortality or behavioral problems from the catch and transport process, and were monitored for resumption of active feeding. After acclimation, Spotted Seatrout were surgically implanted with inactive "dummy" transmitters to evaluate surgical procedures. Dummy transmitters were identical replicates of the Vemco (AMIRIX Systems, Halifax, Nova Scotia) V13 transmitters (36-mm length × 13-mm diameter, 6-g weight in water, 11-g weight in air) that are typically used in movement studies. Due to limited holding capacity, this investigation was completed in two separate trials. Fish were held in the same tank for each trial, and water parameters were maintained with similar, stable conditions by TPWD-MDC staff.

Six treatment groups (nine fish in each treatment for a total of 54 fish) were used to investigate two incision locations (midline and off-midline) and three suture materials (braided, monofilament, and staples). Control procedures (two fish in each treatment for a total of 12 fish) included each of the six surgical treatments without dummy transmitter implantation (Table 1). Four additional fish served as tank controls: two fish were held in the cradle for 3 min (the approximate surgical duration) without surgery, and two fish were transferred directly to the recovery tank. Food was withheld from fish 24 h prior to surgery (Summerfelt and Smith 1990; Wildgoose 2000).

Surgical procedures were randomly alternated between treatment groups to decrease any effect of surgeon experience (Wagner and Cooke 2005). Using approved Institutional Animal Care and Use Committee (IACUC) protocols, fish were not anesthetized and were placed dorsoventrally in a surgical cradle designed to allow the head and gills to remain submerged in seawater. A 2.5-cm incision (#10 scalpel blade) was made posterior to the pelvic fin insertion either directly on the midline or approximately 1.5 cm lateral to the midline. Transmitters were disinfected in a 12.9% solution of benzalkonium chloride and rinsed in sterile water before insertion into the peritoneal cavity (Mulcahy 2003). A uniquely numbered anchor tag (Floy Tag, Seattle) was placed at the posterior end of the incision for individual fish identification. Incisions were closed with a single suture secured with a surgeons knot when using absorbable braided suture material (Vicryl, 4-0 PS-2 cutting; Ethicon, Somerville, New Jersey) or absorbable monofilament suture material (PDS II, 4-0 PS-2 cutting; Ethicon), or three surgical staples (Appose ULC 35; Tyco, Gosport, UK), the minimum number of sutures to ensure adequate closure. The holding tank was checked daily for the first week postsurgery to monitor for mortality, transmitter loss, and anchor tag loss. During the next 3 weeks fish were checked three times weekly at scheduled feedings. Dead fish were removed and evaluated immediately upon discovery. After 31 d, fish were euthanized with a lethal dose of tricaine methanesulfonate (MS-222), evaluated, and assigned incision healing scores adapted from Wagner and Stevens (2000; Table 2).

Data analysis.—We use logistic regression (forward stepwise regression) to determine what surgical factors influence Spotted Seatrout survival. Model selection was performed using Akaike's information criterion (AIC) and the likelihood ratio statistic for entering and removing variables (Diamond and Campbell 2009; Froeschke et al. 2013). Additionally, model validation was conducted using a Hosmer and Lemeshow goodness-of-fit test that tests the null hypothesis that there is no difference between observed and model-predicted values. We tested the following variables in the logistic regression: suture material, incision location, size (mm TL), sex, surgery time, transmitter : body mass ratio, incision length, whether the fish had a dummy transmitter, and the interactions of sex and incision location and sex and size. Logistic regression (forward stepwise regression) was also used to assess what factors influenced internal transmitter retention. Similar to above, AIC and likelihood ratio statistics were used for model selection, and Hosmer and Lemeshow goodness-of-fit test was used for model validation. Transmitter retention tests excluded all mortalities and surgical control fish because they did not have an internal transmitter. The transmitter retention

TABLE 1. Experimental design and sample size (*n*) for each treatment group for laboratory trials of implanting acoustic transmitters in Spotted Seatrout.

Treatment	Description of treatment	*n*
MM	Midline incision closed with monofilament suture	9
MS	Midline incision closed with staple	9
MV	Midline incision closed with braided (Vicryl) suture	9
OMM	Off-midline incision closed with monofilament suture	9
OMS	Off-midline incision closed with staple	9
OMV	Off-midline incision closed with braided (Vicryl) suture	9
Surgical controls	Two surgical controls per treatment group, no transmitter implanted	12
Handling controls	Two fish held in the surgical cradle for 3 min each, no surgery	2
Tank controls	Two fish transferred tanks only, no surgery	2

TABLE 2. Scoring criteria used to describe macroscopic appearance and healing of incisions for Spotted Seatrout implanted with acoustic transmitters. Inflammation is defined as red raised skin around the incision and suture sites. Adapted from Wagner (1999).

Score	Scoring criteria
0	Incision completely closed, no inflammation present
1	Incision closed, some inflammation present
2	Incision held in proximity, but not completely closed; little-to-moderate inflammation
3	Incision held in proximity, but not closed; moderate inflammation
4	Incision partially open, moderate-to-high inflammation
5	More than 50% of incision open; moderate-to-high inflammation
6	Completely open wound; high inflammation

variables used in the model were: suture material, incision location, size (mm TL), sex, transmitter : body mass ratio, incision length, and the interactions of sex and incision location and sex and size. Incision healing scores were analyzed using a two-way ANOVA, with suture material and incision location as fixed main effects ($\alpha = 0.05$). All analyses were conducted in SAS software (version 9.2; SAS Institute, Cary, North Carolina).

RESULTS

Wild-caught Spotted Seatrout ranged in size from 270 to 553 mm TL, and of the fish that underwent surgical procedures, 17 were male and 49 were female. The mean size of male fish was 349 mm TL (SE, 11.7), and female mean size was 388 mm TL (SE, 7.8). The size distribution of females and males are similar, although female fish were captured more frequently and several were larger than male fish (Figure 1). Surgery time ranged from 73 to 270 s, with a mean of 144 s (SE, 5.3).

Generally, there was high survival of Spotted Seatrout during the experiment. A total of 66 fish underwent surgical procedures and 49 survived. Survival was 100% for nonsurgical controls (handling controls and tank controls), 75% for surgical controls, and 74% for surgically implanted fish (Figure 2). Mean transmitter : body mass ratio of fish that were implanted with transmitters and survived ($n = 40$) was 2.32% (SE, 0.16), and 2.82% (SE, 0.21) for fish that did not survive ($n = 14$).

Fish survival was modeled using logistic regression, and the stepwise forward model development is described in Table 3. The only significant factors contributing to survival of Spotted Seatrout were sex and surgery time (Table 3). The model was a good fit to the data based on the Hosmer–Lemeshow statistic
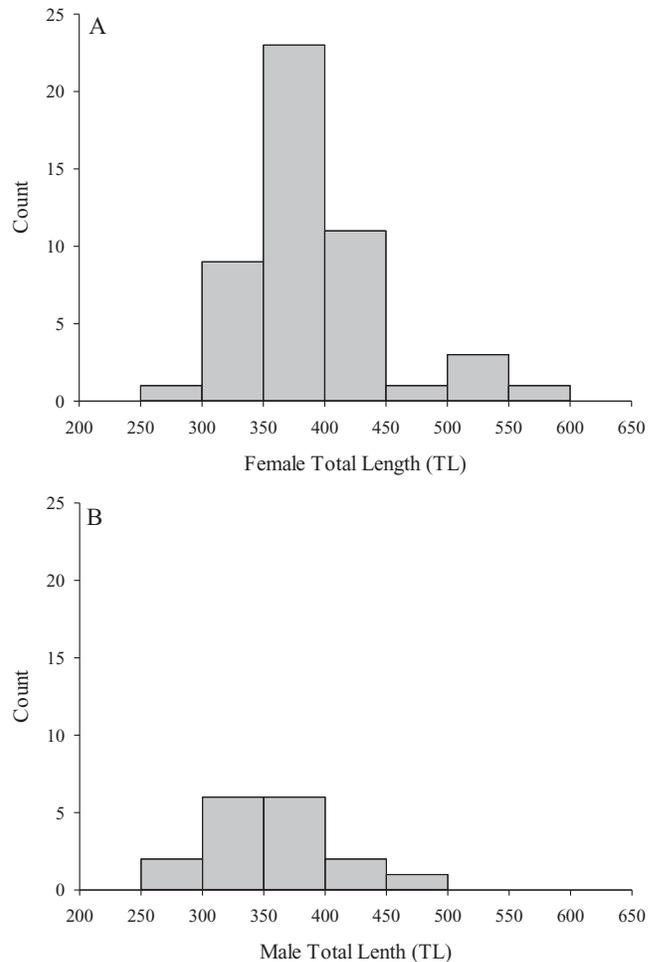
FIGURE 1. Spotted Seatrout size frequency histogram of **(A)** female fish ($n = 49$) and **(B)** male fish ($n = 17$) that underwent surgical procedures, not including the tank control fish.

FIGURE 2. Percent survival for surgical trial Spotted Seatrout. Nonsurgical fish were transferred to the tank only, surgical control fish had surgery without transmitter implantation, and surgical implant fish received an internal dummy transmitter. Numbers at the bottom of the bars indicate sample size (n) for each group.

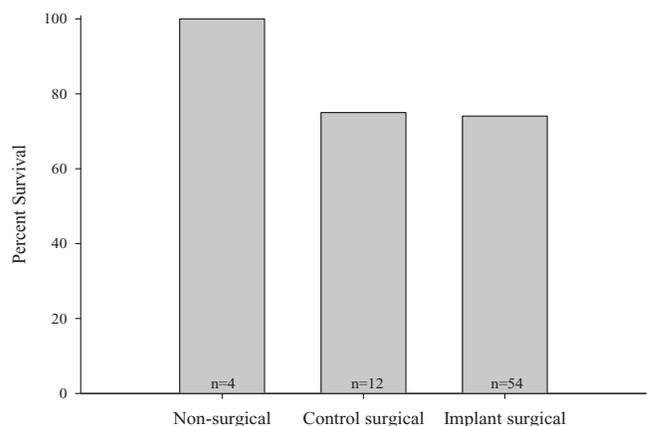TABLE 3. Results of logistic regression analyses of Spotted Seatrout survival. The variables included in the survival analysis were: suture material, incision location, size (mm TL), sex, surgery time, transmitter : body mass ratio, incision length, whether the fish had a dummy transmitter, and the interactions of sex and incision location and sex and size. Variables were added in a forward stepwise regression and were retained if they significantly improved the model based on likelihood ratio statistic and AIC.

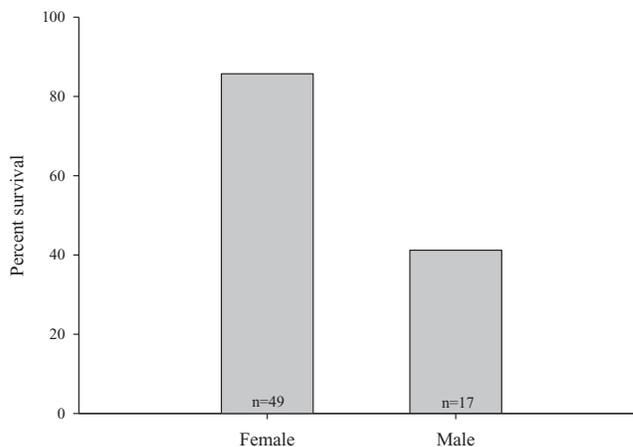| Logistic regression factors	df	Likelihood ratio	p	AIC
Sex	1	11.498	<0.001	66.596
Sex + time	2	15.646	<0.001	64.448

FIGURE 3. Percent survival of female and male Spotted Seatrout, including both surgical control fish that had surgery without transmitter implantation and surgical implant fish that received an internal dummy transmitter. Numbers at the bottom of the bars indicate sample size (n) for each group.

($p = 0.486$). Survival was not influenced by transmitter implantation, suggesting the actual process of undergoing surgery affected survival of Spotted Seatrout, even with no transmitter implanted. Additionally, female fish were approximately 10 times more likely than male fish to survive surgery (Table 4), and we found that female fish had much higher survival (85.7%) than male fish (41.2%; Figure 3). Surgery time also predicted fish survival; in general, the faster the surgery was performed, the more likely it was for the fish to survive. The odds ratio showed that for every second that the surgery time was reduced, the odds of increasing survival were 1.5% (Table 4). Of the fish that survived, surgery duration for the majority of these fish (89%) was less than 160 s.

A total of 40 fish survived that had an internal transmitter implanted. The logistic regression model used to determine what factors influenced internal transmitter retention showed that none of the factors we measured were significant ($\chi^2 = 5.499$, df = 8, $p = 0.703$). Transmitter retention was 65% for fish with an off-midline incision and 70% for fish with a midline incision. Among suture materials, monofilament had the highest transmitter retention (82%), followed by surgical staples (63%) and braid (62%). Although size did not influence transmitter retention, transmitters were clearly visible, creating back-pressure on the incision, body wall, or both in fish smaller than 405 mm TL. Generally, larger fish had much more peritoneal space, allowing the transmitter to easily fit into their body cavity without any visible signs of pressure on the body wall or incision.

Incision healing assessed both the suture material and incision location. There was no significant interaction between incision location and suture material ($F = 0.82$, df = 2, $p = 0.445$), and there was also no difference ($F = 0.02$, df = 1, $p = 0.903$) in mean incision healing between midline and off-

midline incision placement. The mean incision score for an off-midline incision location was 0.75 ± 0.30 SE and midline incision was 0.76 ± 0.25 SE. There was also no significant difference in mean incision healing among suture materials ($F = 0.37$, df = 2, $p = 0.695$). The mean incision score was the highest for braid (mean $= 0.93 \pm 0.38$ SE), followed by staples (mean $= 0.85 \pm 0.33$ SE), and monofilament (mean $= 0.47 \pm 0.27$ SE).

Suture retention varied among the three materials used. Staples had the lowest suture retention (40%), including tag expulsion; thus, this method is not recommended. Braid and monofilament had much higher retention rates (71% and 93%, respectively). External anchor tags placed at the posterior end of the incision (a common location for many investigators) to identify individual fish were problematic, resulting in frequent expelled tags along with transmitter losses. This was particularly true for smaller fish with higher transmitter : body mass ratio; however, we were still able to identify fish by TL, incision location, and suture type. There was a 24.3% loss of the external anchor tags, and of those fish that did retain the external tags, 73.4% were inflamed at the exit point or the anchor had prevented the incision from healing completely. Consequently, this type of identification tags should be discouraged in future telemetry studies, and we instead recommend external dart tags placed just lateral of the first dorsal fin.

TABLE 4. Odds ratio results from significant logistic regression effects of Spotted Seatrout survival as well as the model intercept regression coefficient.

Variable	Regression coefficient	Odds ratio (exp[estimate])	95% Confidence limits	
Intercept	1.733			
Sex (female versus male)	2.321	10.184	2.577	40.252
Time	−0.015	0.985	0.970	1.000

DISCUSSION

This study was designed to evaluate surgical techniques to determine the best method to implant acoustic transmitters in Spotted Seatrout. We determined implantation in this species is viable, and generally fish survive and retain implanted transmitters. The primary factors that influenced survival were sex of the fish and surgery time, and we were unable to identify any factors that influenced transmitter retention. The results show that most surgical methods are equally viable (except staples—see below); however, the probability of survival is higher for female fish and surgeries that are conducted in 160 s or less.

Differences in survival between male and female Spotted Seatrout may be attributed to the morphological differences between sexes. Male fish have pronounced sonic muscles which vibrate the gas bladder and produces sound during spawning (Bortone 2003). The surgery treatments with an off-midline incision required a cut through these sonic muscles in male fish. This could have been detrimental to healing and survival, causing differences in male and female survival rates, although not detected by our analyses. Ideally, this study would have included an equal number and size of male and female fish, including large male trout, but there is no reliable way to determine the sex of Spotted Seatrout without invasively examining the gonads and this procedure may impact survival. Although we collected fewer male fish than females in this study and some were smaller than females, we found no relationship between size of fish and survival, or the interactions between size and sex and incision location and sex. Thus, the cause of survival differences between sexes is still somewhat unclear. However, to increase the probability of survival after transmitter implantation and reduce the risk of having to cut through male sonic muscles, we suggest targeting fish greater than 425 mm TL to implant V13 transmitters for field studies, as female Spotted Seatrout are generally more abundant at larger sizes (Bortone 2003). We also observed that the size of larger fish facilitated the surgical procedure because there was more space in their peritoneal cavity for the transmitter, which generally decreased surgery and handling time. Additionally, smaller fish were observed to have less room for the transmitter in the peritoneal cavity and thinner body walls, which placed more back-pressure on incision sites. This pressure likely prevented proper incision healing, caused further internal damage, and decreased survival and transmitter retention among treatments. Moreover, implantation experiments on other species have recommended that transmitter : body mass ratio be less than 2% (Jepsen et al. 2005), and observations from our early preliminary studies showed high mortality in small fish with high (3% or greater) ratios. Thus, a major recommendation from this study is that the transmitter : body mass ratio should be no more than 2.5% for Spotted Seatrout.

Surgery time was also an important factor influencing Spotted Seatrout survival. The majority of the fish that survived underwent surgical procedures in 160 s or less, suggesting some stress-related mortality from the surgical process. Time was an important factor because as surgery time increased, the stress on the fish also likely increased, which may be the cause of increased mortality (James et al. 2007). Additionally, fish were mostly likely stressed before the surgery due to the capture method of individual fish. Lowerre-Barbieri et al. (2013) conducted similar laboratory trials with Spotted Seatrout and also found that fish became stressed and agitated from capture methods presurgery. Therefore, we suggest for future field studies to hold Spotted Seatrout in small, oxygenated tanks (e.g., 143-L insulated cooler) to ensure their capture for surgery is fast and easy, producing the least amount of induced stress before the surgery begins; this will likely increase their probability of survival (Lowerre-Barbieri et al. 2013).

Survival rates were not different between control and implant treatment groups, suggesting that having a transmitter did not influence survival and that the surgery process is the primary cause of mortality. These findings are similar to those of Hall et al. (2009), who also suggested that surgery alone is the primary source of mortality. Neither survival nor transmitter retention were affected by incision placement or suture material. Incision healing scores were also not different between midline and off-midline incision locations, or suture materials, showing that incision location and suture material has little effect on healing or survival. We found that braided suture material did not cause additional irritation from suture retention compared with monofilament, as other researchers have found (Wagner and Cooke 2005). Cooke et al. (2003) found no inflammation differences between braided silk and monofilament suture, but did report better incision healing and ease of use with braided silk suture material. Although braid had slightly higher healing scores than monofilament and even staples, differences were not significant, and we found that braided sutures were much easier to use, particularly tying the surgeon knot to secure the suture, thus reducing handling time.

Aside from surgical techniques, we observed other factors that appeared to influence fish survival and transmitter retention that, in some cases, were untestable. Perhaps these observed differences were not statistically detected due to small sample sizes. Nonetheless, we feel these are important observations for investigators to consider when surgically implanted transmitters in Spotted Seatrout or other Sciaenid species. We noticed several problems with the anchor tags we used to identify individual fish. Because these tags were located in the incision, they induced irritation that may have contributed to fish mortality, loss of transmitters, and poor healing. Anchor tags are often inserted into the incision as the preferred application method for external identification. This method avoids additional puncture wounds and has been the preferred passive tag implementation for many studies. Vogelbein and Overstreet (1987) assessed tissue responses as a result of anchor tag insertion and reported favorable findings for

anchor tag retention in Spotted Seatrout, with minimal complications due to inflammation or infection; however, placement incisions were only 8–10 mm long and did not include insertion of a transmitter. Incisions in this study were approximately 25 mm long, and in several cases the anchor of the tag was protruding out the incision, apparently hindering the healing process, which may have influenced transmitter retention. For field studies requiring external identification of fishes (including Spotted Seatrout and most other fishes), we suggest modifying protocols by using external dart tags placed just lateral of the first dorsal fin to decrease interference with incision healing and improve transmitter retention. We also do not recommend the use of anesthesia. Currently, there is no anesthetic that is approved by the Food and Drug Administration for use on food fish without an extensive holding period. Spotted Seatrout are often targeted by anglers with the intention of harvest and consumption, and because we recommend targeting fish that are at least 425 mm TL for future field studies, they could be consumed by recreational anglers. Furthermore, fish need to be tagged and released immediately to minimize behavioral alterations, and the use of anesthesia without adequate recovery time increases potential for predation. Anesthesia can take several minutes to be metabolized through the system once postsurgical recovery has begun. Therefore, we were unable to use anesthesia prior to surgical implantation, but based on results from this study do not recommend its use for implantation of transmitters in Spotted Seatrout. This type of experiment without anesthesia must be approved and performed under the guidance of IACUCs, as was this study (IACUC 02-09, Texas A&M University–Corpus Christi [TAMU-CC]). We also consulted with veterinarians and other animal use experts as to our procedures to minimize pain, distress, and handing time. It is possible that by not using anesthesia, we introduced a greater level of immediate discomfort to the fish; however, the tagging process was extremely brief, along with shorter handling and recovery times. Moreover, Rose et al. (2014) recently reviewed pain pathways and animal procedures for fishes and suggested that there should be no additional pain and discomfort to the fish when anesthesia is not used.

Overall, surgical implantation of acoustic transmitters was very successful, and there was no particular treatment that showed distinct differences in survival and transmitter retention; therefore, it is feasible for researchers to use their surgical method of preference (Harms and Lewbart 2000). However, we did discover techniques and locations that facilitated the implantation process, improved efficiency, and will likely improve survival of Spotted Seatrout. For field studies, we recommend targeting Spotted Seatrout greater than 425 mm TL for implantation of V13 transmitters, as these fish are more likely to be female and sex-specific mortality would thus be reduced, and ensuring the transmitter : body mass ratio is under 2%. If studies are interested in sex-specific movement patterns, smaller tag sizes should be selected to improve male

survival. We also suggest conducting surgeries in 160 s or less without anesthetic to minimize surgical distress. Although we found no differences in suture material or location, we recommend off-midline incision placement to reduce transmitter-induced pressure on midline placed incisions. We also suggest using two sutures to close the incision to help ensure transmitter retention and using braided suture material for its ease of manipulation, decreased irritation at the incision site, and fast absorption. We recommend against the use of surgical staples because they easily pulled through the flesh, had the lowest suture retention, and are not absorbed by the fish, which resulted in frequent transmitter loss. This experiment provides useful insight to surgical methodology for future acoustic telemetry tracking studies on this popular sport fish. The information provided here will help bolster investigator confidence in surgical survival and transmitter retention, and improve techniques for field trials and acoustic detection of Spotted Seatrout; it can also be applied to other fishes, particularly other Sciaenid species.

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