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Ingested Transmitter Expulsion Rates in Striped Bass

US DEPARTMENT OF COMMERCE
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Ingested Transmitter Expulsion Rates in Striped Bass

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ABSTRACT

Researchers frequently use acoustic telemetry to monitor fish behavior and survival and to investigate population dynamics of many species. Managers use this information to guide decision making for protected species, recreational, or commercial fisheries management. Therefore, it is important for researchers to be confident that they are monitoring their tagged animal and not a predator. An important variable in determining study fish movement versus predator movement is expulsion rates of a consumed transmitter. We evaluated the transmitter expulsion rate of locally known Atlantic salmon (*Salmo salar*) smolt predators, which are age 2-4 (40-54 cm) striped bass (*Morone saxatilis*) that received a transmitter by 2 different ingestion methods. The volitional ingestion group (n = 20) consumed Atlantic salmon smolts surgically implanted with transmitters, and the forced insertion group (n = 6) had transmitters manually inserted by researchers. Minimum, mean, and maximum gastric expulsion rates were highly variable and not significantly different between ingested (3, 17, 58 d) and inserted (6, 24, 76 d) groups. We did not observe a correlation between expulsion rates and last recorded measures of length (p-value [P] = 0.175) or weight (P = 0.233). Measurements of expulsion rates for specific predators of study fish can be helpful to assess movements of the detected transmitters in a nontarget species. These methods can assist researchers in identifying suspicious detections and help ensure the collection of accurate data. However, our study indicates the evacuation rates for transmitters consumed by predators can be variable and other means (e.g., behavior analysis) might be needed to identify predation events.

INTRODUCTION

Increasingly, acoustic telemetry is used in the fisheries field to monitor and investigate population dynamics of many species (Hussey et al. 2015). Programs vary widely in their objectives from monitoring movement and behavior within a defined area (Cagua et al. 2015) to estimating survival rates in a temporal and spatial context (Stich et al. 2014) to identifying preferred travel corridors during long distance migrations (Kocik et al. 2009). Technology advances also enable researchers to study a vast array of marine organisms ranging from jellyfish to top predators (Hussey et al. 2015; Harcourt et al. 2019). Tracking individual movements and monitoring environmental parameters also informs our understanding of ocean habitat use and preference (Lacroix et al. 2004; Renkawitz et al. 2012).

Nonetheless, it is essential for investigators to realize they are tracking a transmitter's movements and not necessarily the organism they originally tagged. Researchers have identified occurrences of predation on their subject specimens during telemetry investigations (Beland et al. 2001; Serrano et al. 2009; Thorstad et al. 2011; Lacroix 2014; Romine et al. 2014; Gibson et al. 2015). While identifying predation may not be the original intent or goal of a study, it is imperative to identify such events to separate target species' behavior and movement from that of a predator. Failure to identify such scenarios may inadvertently lead to the misinterpretation of data with the potential to artificially inflate survival estimates or misrepresent preferred habitat use and movement characteristics within specific investigations (Thorstad et al. 2012; Romine et al. 2014; Gibson et al. 2015).

Tracking studies in the Northwest Atlantic Ocean since the mid 1990s informed our understanding of emigrating Atlantic salmon (*Salmo salar*) smolt behavior, survival, and ecology (Lacroix 2008; Kocik et al. 2009; Halfyard et al. 2012; Stich et al. 2014). Atlantic salmon are an endangered species in the United States (USFWS and NOAA 2009) and in several southern Canadian regions (COSEWIC 2010). One factor believed to be contributing to their decline is predation (Montevecchi et al. 2002; Friedland et al. 2012). Many studies reported or indicated the potential for high levels of predation on emigrating smolts by both avian (Dieperink et al. 2002; Montevecchi et al. 2002; Halfyard et al. 2012; Hawkes et al. 2013) and piscine predators (Hvidsten and Lund 1988; Jepsen et al. 2006; Serrano et al. 2009; Thorstad et al. 2011).

While it is widely noted that predators may consume tagged specimens, we found limited information within the literature investigating the intragastric expulsion rate of a transmitter when a predator consumes a tagged specimen. Because earlier telemetry studies positively identified striped bass (*Morone saxatilis*) as a predator on salmon smolts within our geographical area (Beland et al. 2001) and they are known to prey on salmonids elsewhere (Blackwell and Juanes 1998; Grout 2006; Nobriga and Feyrer 2007), they are a species of interest for Atlantic salmon ecology studies. Our goal was to study the intragastric expulsion rate of striped bass that consume acoustic-tagged smolts. Our objective was to quantify the amount of time a consumed transmitter might remain in striped bass which may aid researchers in identifying nonsmolt movement data during telemetry investigations. Forced insertion was utilized to see if that tagging method yielded similar expulsion rates. For this study, we define the term “expulsion rate” as the number of days the consumed transmitter remained in the stomach of the striped bass. Other studies use varying terms including “retention time” and “gastric evacuation” to define the same metric.

METHODS

Setup and Maintenance

We constructed sham transmitters to replicate Vemco V8 (Innovasea Marine Systems Canada, Inc, 20 Angus Morton Drive, Bedford, NS, Cananda, B4B0L9) acoustic transmitters. The transmitters consisted of West System 2-part epoxy cast into a V8 transmitter mold with a lead weight and a tricolor-coded spaghetti tag embedded to allow for individual transmitter identification. Transmitters were 8 mm in diameter and 30 mm in length with an average weight of 4.15 g (standard deviation [SD] = 0.08).

A total of 31 striped bass were collected by angling in October 1997 and transported to the National Marine Fisheries Service, Northeast Fisheries Science Center Aquarium (Woods Hole, MA) for the duration of the experiment. Fish were kept in a 2 m diameter by 1.1 m deep circular tank with constant water flow and 2 air stones for added oxygenation. Tank temperatures ranged between 17.9 and 20.0ºC for the duration of the study. Fish were fed immediately upon being placed in the tank and were subsequently fed on a 3day per week schedule until satiation. Their diet was predominately Atlantic herring (*Clupea harengus*) and to a lesser extent short finned squid (*Loligo pealeii*). After a 30 d acclimation period, all fish were anesthetized with tricaine methanesulfonate (MS-222) (100 mg / 1000 mL), total lengths (TL) and whole weights were collected, and a Carlin tag was applied for individual identification. Throughout the experiment the tank was inspected for expelled tags daily. Ingestion of sham transmitters and smolts occurred after a total acclimation period of 48 d. Sham transmitters were inserted into hatchery-reared Atlantic salmon smolts obtained from the USFWS Green Lake National Fish Hatchery. Smolts averaged 173 (SD = 9.6) mm TL and weighed 54.5 (SD = 10.2) g, and transmitters were surgically implanted into the smolts peritoneal cavity following procedures outlined in Kocik et al. 2009.

Volitional Ingestion Group (n = 20)

Striped bass were taken off feed to encourage voluntary ingestion 5 days prior to being offered a tagged Atlantic salmon smolt. The tank holding the striped bass was divided into 3 sections (holding, feeding, and recovery) with a polyvinyl chloride (PVC) partition. Individual striped bass were randomly netted from the holding section and placed in the feeding section. The fish was offered a tagged Atlantic salmon smolt. Once the smolt was fully ingested, the striped bass was relocated to the recovery section. We repeated the process until 20 transmitters were ingested.

Forced Insertion Group (n = 6)

An additional 6 striped bass were anesthetized with MS-222 and force fed sham transmitters. With the aid of a blunt probe, sham transmitters were inserted into the gastric cavity via the esophagus and past the insertion of the pectoral fins. Each fish in this group was offered an untagged Atlantic salmon smolt after a brief recovery period, which they immediately consumed. After ingesting the smolt, the striped bass was relocated to the recovery section. The process was repeated with another 5 striped bass.

Control Group (n = 5)

The remaining 5 striped bass were offered untagged smolts, which they immediately consumed. The partition was then removed from the tank allowing all 3 striped bass groups to mix. Daily inspections for shed sham transmitters occurred until all transmitters were shed (76 d). When a sham transmitter was found, the date, time, and tricolor code were recorded. Fish that had expelled their sham transmitters were not removed from the population so as not to provide additional stress to the study population.

Statistics

We used Statgraphics Centurion XVII for statistical analysis. To compare volitional ingestion, forced insertion, and control group biological characteristics, we used an ANOVA test to compare between groups for both initial and final total length and weight. To examine individual growth, we calculated Specific Growth Rate (SGR) with the following formula:

$$SGR = (\ln W_2 - \ln W_1) / (t_2 - t_1),$$

where W_1 is weight at time 1 (t_1); W_2 is weight at time 2 (t_2); t_1 was the start day; and t_2 was the end day. We used a Kruskal-Wallis test to compare SGR among the 3 groups because of non-normality in those data. We used ANOVA to evaluate expulsion rates in regards to final total length and weight and to compare expulsion rates versus ingestion method. A regression analysis was used to compare the impact of SGR on expulsion rates.

RESULTS

After the initial 30 day acclimation period, striped bass total lengths ranged from 40.4 cm to 54 cm with a mean of 46.4 cm (SD = 35.05). Weights ranged from 0.83 kg to 1.93 kg with a mean of 1.27 kg (SD = 0.2867). By the end of the study (119 d), striped bass mean total length increased 5.4 cm and mean weight increased 0.66 kg for a final mean of 51.9 (SD = 34.28) cm and

1.94 (SD = 0.391) kg. The transmitter weight to striped bass body weight ratio did not exceed 0.5% for any individual over the course of the experiment. Total length and weight for the 3 groups (volitional ingestion, forced insertion, and control) were not significantly different at the beginning (ANOVA P = 0.471, P = 0.611) nor end (ANOVA P = 0.889, P = 0.929) of the study. After ingestion of the sham transmitters, striped bass began feeding between 1 and 3 days later with a mean of 2.36 (SD = 0.64) d. Fish appeared to be in good health and fed aggressively throughout the experiment. Ingestion method did not affect Specific Growth Rate (SGR) (Kruskal-Wallis P = 0.348) over the duration of the study.

All 26 sham transmitters were recovered. Expulsion rates between volitional ingestion and forced insertion of transmitters were not significantly different (P = 0.369), so we pooled data. Minimum, mean, and maximum expulsion rates were 3, 24, and 76 d. We looked at standard expulsion rates for 25%, 50%, and 75% and found 11, 18, and 28 d to expulsion. We did not observe a correlation between expulsion rates and final length (P = 0.175) or final weight (P = 0.233). Additionally, there was no relationship between expulsion rate and striped bass SGR (P = 0.26).

DISCUSSION AND CONCLUSIONS

Acoustic telemetry allows scientists to monitor and investigate animal movements across dynamic systems. However, researchers must be certain when they are collecting information on their target species and when they may be monitoring predators that have consumed them. Our study illustrates that the length of time in which a predatory species (striped bass) may be carrying an active transmitter was quite variable. Retained transmitters may be providing erroneous information to a dataset if the act of predation is not quickly recognized and noted in analysis. Spurious data must be removed to provide an accurate assessment of survival, movement dynamics, and habitat use of the target species.

Our study found that 50% of the consumed transmitters remained in a striped bass for over 2 weeks. Other studies found similar expulsion rates for other smolt piscine predators (i.e., Atlantic cod [*Gadus morhua*] and saithe [*Pollachius virens*]) (Winger et al. 2002; Thorstad et al. 2012). Delayed (Winger and Walsh 2001; Klinard et al. 2019) or more rapid (Schultz et al. 2015) expulsion rates for consumed transmitters implanted in juvenile salmon may be attributed to differences in temperatures experienced during studies. Temperature can affect the metabolic rate of fish and in turn, expulsion rates (Dos Santos and Jobling 1991; Schultz et al. 2015; Klinard et al. 2019). Our study occurred under temperatures representative of the higher end of the smolt emigration period or slightly beyond (Otero et al. 2014). In addition to temperature, differences in range of mobility in study areas/set-up may affect expulsion rates. Having a greater range of mobility and experiencing different environments (depth, flow, etc.) potentially contributes to differences in transmitter expulsion rates (Schultz et al. 2015). Finally, more rapid expulsion rates in other studies may occur as the result of using smaller and lower mass transmitters (Schultz et al. 2015).

Atlantic salmon smolt estuarine migration occurs between April and June, and while migration is generally downstream, direct, and rapid (Finstad et al. 2005; Renkawitz et al. 2012), short reversals are also exhibited during migration (Kocik et al. 2009; Dempson et al. 2011; Hawkes et al. 2017). Depending on estuarine length, swim speed, and the number of reversals made by a smolt, residence times in an estuary can range from a few hours to over 2 weeks (Kocik et al. 2009; Dempson et al. 2011; Hawkes et al. 2017).

Migrating Atlantic salmon smolts in our local telemetry studies average 3.4 d in the Penobscot Estuary (Renkawitz et al. 2012) and up to 8 d in the Narraguagus Estuary (Kocik et al. 2009). Acoustic tagged smolts consumed by piscine predators within these systems may appear to have successfully emigrated if that predator exits the system before expelling the transmitter, thus inflating survival estimates. Conversely, a piscine predator, such as a striped bass, may remain stationary or use limited movements for several days outside the detection range of receivers (Ng et al. 2007) and expel the transmitter. This scenario would classify the smolt as unsuccessful and underestimate predation events within the study. The longer the predator of an acoustic tagged smolt remains within the receiver array, the greater the likelihood of identifying a predation event through behavioral differences between the species. If the study array coverage allows for identification of long reversals or swim speeds exceeding study species (Atlantic salmon) norms, researchers may identify these predation events, but not necessarily the predator species. Additionally, using analytical methods and models as an alternative to subjectively evaluating individual tracks may also elucidate predation events (Romine et al. 2014; Gibson et al. 2015; Daniels et al. 2018).

Acoustic sensor transmitters that provide environmental data (i.e., temperature and/or depth) may also assist in determining predation events by examining the differences between tagged species and predator biology and behavior. Atlantic salmon smolts typically migrate near the surface (Fried et al. 1978; Davidsen et al. 2008; Plantalech Manel-la et al. 2009; Renkawitz et al. 2012) while many of their piscine predators such as Atlantic Cod (Hobson et al. 2007; Thorstad et al. 2012) and saithe (Armannsson and Jónsson 2012; Thorstad et al. 2012) utilize much greater depths. Newer predator transmitters are showing promise in the ability to identify predation events when the transmitter's inert polymer covering is broken down through the digestion process (Halfyard et al. 2017; Daniels et al. 2019). These transmitters report temperature after prey are consumed, helping to identify not only a predation event, but what type of predator is most likely responsible (e.g., piscine, marine mammal, avian). With the accompanying depth and temperature information from sensor transmitters, researchers are able to more accurately identify predation events (Hanssen et al. 2021) and also specify the type of predator involved. However, these are emerging technologies, and adjustments to increase response accuracy will continue to evolve (Lennox et al. 2021).

Undoubtedly, acoustic telemetry will continue to provide insights into the movement behavior, survival, and population dynamics of many species. Researchers will continue to collect valuable information to provide to managers and enable them to make informed decisions for the benefit of the species survival. Yet, attention needs to be given to the evaluation of telemetry tracks in order to prevent the inclusion of erroneous data from a nontarget specimen into datasets. Having knowledge of ingested transmitter expulsion rates, movement patterns, and behavior of predators that may consume tagged specimens will greatly assist researchers in identifying predation events. Novel behavior discovered in a species is surely intriguing, yet constant awareness needs to be given to ensure researchers are indeed evaluating the track of their transmitter that remains within their target specimen and not that of a predator.

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