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Estimating survival and the implications of predation

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Summary

Acoustic telemetry methods are routinely used to estimate the survival, movement and relative distributions of fish. In instances where acoustically-tagged fish are consumed by a predator, the consumed tagged fish may be incorrectly identified as live, resulting in inaccurate study conclusions. If acoustic tags using precisely-spaced and uniform coding schemes are employed, a review of the time-series of detections can be used to determine changes in fish behavior, including those indicative of predation. Single receiver detection data can indicate that a predation event has occurred when a tag is shed (defecated) within the detection range. If multiple receivers are deployed to provide fine-scale 2D or 3D fish track data, then quantifiable patterns of swimming behavior can be used to infer predation events. The metrics employed in these behavioral analyses include swimming speed, patterns of fish movement, residence times and others. Recently, a new type of acoustic tag has been developed that can directly measure and report when a tagged fish has been eaten by a piscivorous fish or other predators. These tags were designed to activate in the predator gut to modify the tag signal, while maintaining the information necessary to identify the originally-tagged fish. In tests conducted under controlled conditions in 2013, the predation detection tags (PDT) functioned as designed. Additional field tests are currently underway to evaluate the performance of these tags when implanted in fish released into the natural environment.

Introduction

Historically, there have been declines of fish populations worldwide. In freshwater, salmon migrations have been studied for decades in the USA. On the Columbia River, investigations have been conducted to determine the effects of hydroelectric dams on juvenile salmon survival migrations. Many of these studies have utilized acoustic tags to estimate the juvenile salmon survival through hydroelectric dams using paired release-recapture methods (Burnham et al. 1987 and Skalski et al. 2001). Acoustic tags can also be used to study salmonid behavior to identify sources of mortality in an effort to increase migration survival (Steig and Holbrook 2012). Recently, studies have been conducted on the Sacramento River system to identify areas of salmon smolt mortality (Holbrook et al. 2009). Studies have also investigated novel methods of diverting salmon smolts' migration utilizing lights, bubbles and low frequency sound, as well as physical barriers (Perry et al. 2012). The ability of to determine small and large scale survival along with a method of determining fish behavior by evaluating the two- or three-dimensional (2D or 3D) fish positions has been the driving force in the advances in acoustic telemetry (Ehrenberg and Steig 2002, 2003 and 2009).

Materials and Methods

The results described in this paper utilized an acoustic tag telemetry system developed by Hydroacoustic Technology, Inc. (HTI) which consisted of multiple omni-directional hydrophones attached to an acoustic tag multiple channel receiver (Model 290 Acoustic Tag Receiver (ATR)). These receivers were synchronized utilizing Global Position Satellite (GPS) technology to merge simultaneous data on as many as 64 hydrophones. The acoustic tags used in these studies were the HTI Model 795. The Model 795 acoustic tags are fully programmable for pulse repetition interval (PRI), pulse width, and encoding, with an operating frequency of 307 kHz.

Results and Discussion

The methods used to estimate survival assume that the acoustic tag signal is coming from a freely migrating tagged fish. However, if an aquatic predator consumes the tagged fish, the acoustic signal will still propagate through both fish, and invalidate the basic survival assumption. Various methods have been used to compare predator prey interaction. Using this system with the graphical interface, the raw acoustic tag signal can be viewed in time series. This has become a useful tool to compare raw signals of multiple tagged fish detected on one hydrophone. Examples will be shown of identical tag signals from multiple tags that indicated that each are moving together synchronously. This could only occur if the tags were co-located leading to the conclusion that the tagged prey were all consumed by the same predator.

An advantage of the HTI ATR system is its ability position tagged fish in 2D and/or 3D space. The movement patterns of tagged predators and prey have led to an understanding of the spatial and temporal behavioral characteristics of both groups. From this movement models were developed to determine if and when a prey has been consumed by a predator (Romine et al. 2013).

Figure 1. Verified predation of a tagged chinook smolt (blue spheres) consumed by a tagged striped bass (red spheres). The two tags moved simultaneously for almost two days.

Reviewing the 2D/3D tracks of both prey and predators can clearly show when multiple tagged fish are traveling together suggesting the prey has been consumed by a predator. Figure 1 shows an example of a tagged chinook smolt that was preyed upon by a striped bass.

HTI has developed a tool to determine if a tagged fish has been preyed upon. This utilizes an acoustic tag that sends out a modified signal that is triggered after predation has occurred (PDT), providing a direct measure of mortality.

Acoustic tags provide a powerful tool in estimating fish survival. In addition, acoustic tags provide a useful tool in understanding predator/prey behavior and interactions. Finally, with the new development of the PDT, direct measurements of predation can be determined providing a more accurate understanding and estimate of survival.

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