Evaluating Fish Behavior Using Acoustic Telemetry

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Abstract

Acoustic tagging studies routinely provide information about fish presence and absence. This detection information can be combined into a chronology of time-stamped tag detections to estimate fish survival and fish passage rates, among others. Beyond this simple detection data, if tag transmissions are uniformly spaced with a high level of precision the detection time series can be used to assess fish behavior and events.

Fish behaviors range from simple to complex and some of these behaviors can be interpreted from acoustic tag detection time-series. From single receivers, simple movement toward or away can determine directionality, observed cessation of tag movement can be interpreted as holding behavior, or extended lack of movement as fish mortality or tag defecation following predation. Multiple receiver arrays providing precise measures of two dimensional and three dimensional fish movement can resolve patterns of detections that indicate active fish migration from more wandering movements indicative of resident species or predators.

As more and larger fish populations are studied, more acoustically-tagged fish will interact, increasing the opportunity for accurate interpretation of observed behaviors. Quantifiable behaviors include predator avoidance, schooling/shoaling, predation, and tag defecation. Behavior can be further interpreted when tag detection histories are observed and analyzed in relation to each other and not as isolated tag detections.

Moving Towards & Away

Figure 1 shows a tagged fish detection time-series moving toward and then away from a single hydrophone (hydrophone indicated by pink dot in geo-referenced figure on left).

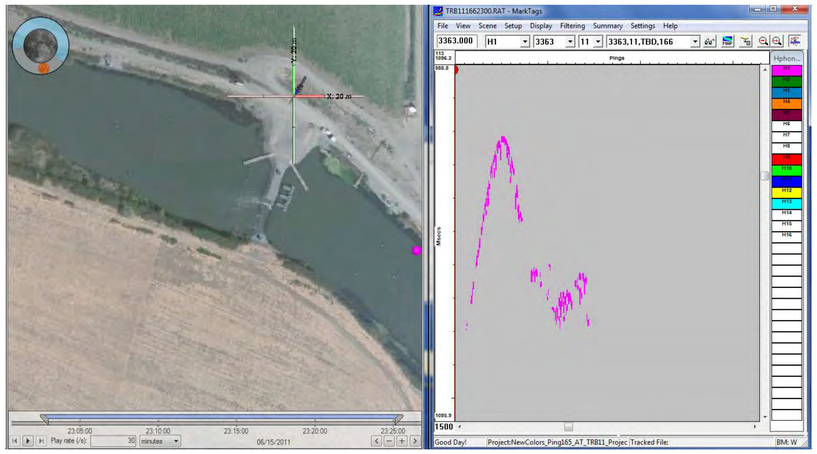


Figure 1. Raw detections from hydrophone. Pink track (on right above) indicates tag movement; vertical scale isolates the returns from one tag code, horizontal scale is time (1 hour). Pink track shows tag initially moving toward the hydrophone, the tag is closest to the hydrophone at the apex and then away from the hydrophone. Cannot determine approach direction using just one hydrophone.

Holding

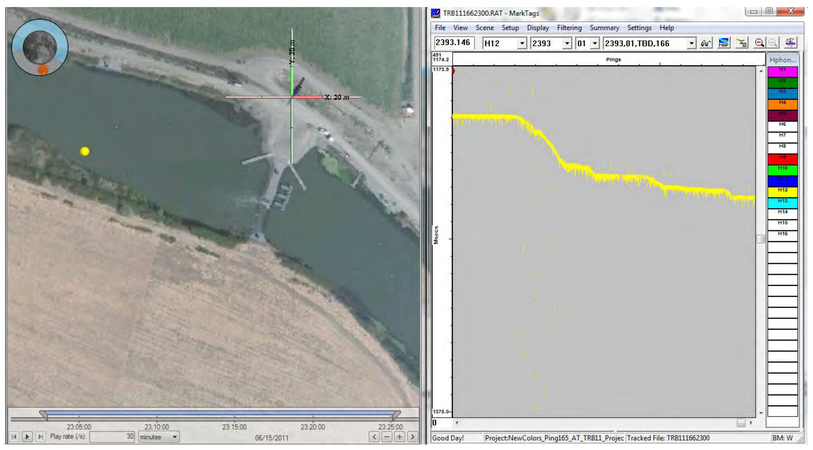


Figure 2. Tag holding position. Yellow track (on right above) indicates intervals of slight positional change followed by an interval of no tag movement (indicated by horizontal track).

Downstream Migration

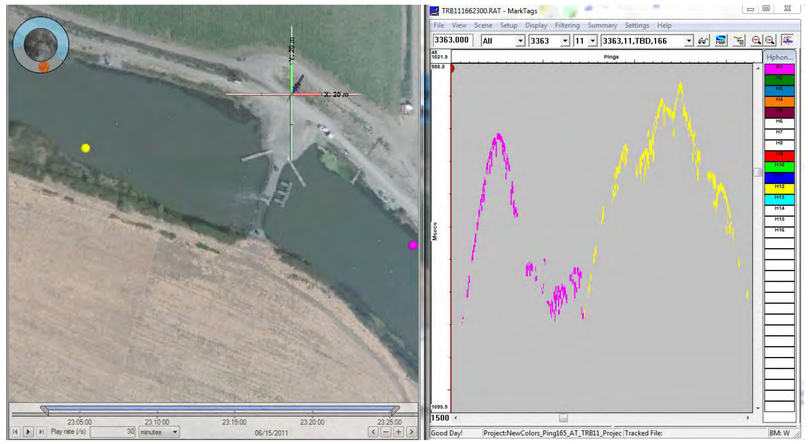


Figure 3. Combining raw detections from two hydrophones (in the geo-referenced graphic above, the upstream hydrophone is indicated by the pink dot and the downstream hydrophone is indicated by the yellow dot). Movement downstream is unequivocal based on the progression of pink to yellow tag detections shown in time-series data above (right).

Migration Route

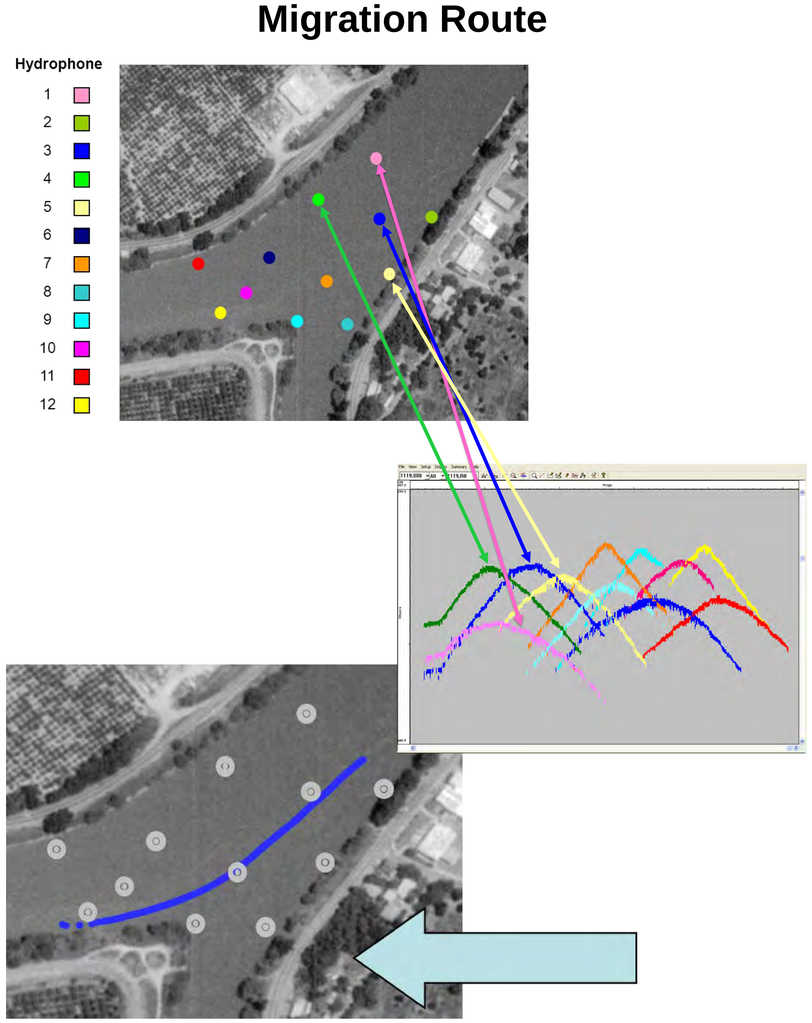


Figure 4. Combining raw detections from several hydrophones show time-series data that indicates migration pathway.

Tag Defecation

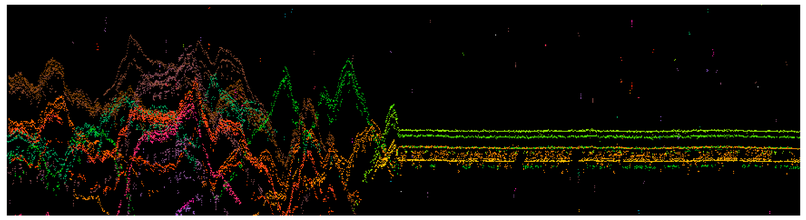
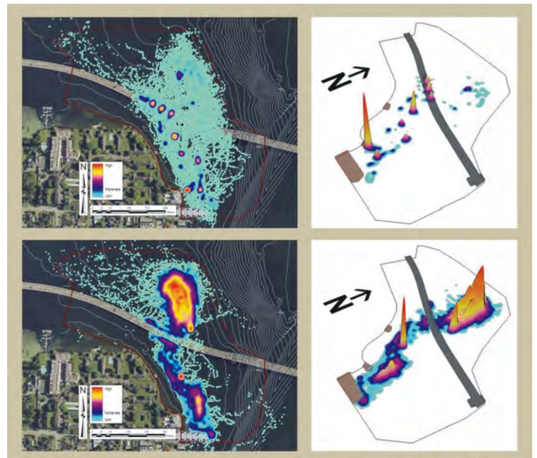


Figure 5. Tag defecated within hydrophone array. Raw detection data from tag that suddenly stops all movement within the hydrophone array. Each colored line represents data from one individual hydrophone.

Diel Periodicity



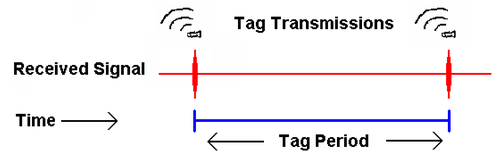
Day and night density plots of northern pikeminnow #4667 at State Route 520 Bridge study site, summer 2007.

Figure 6. Track history (left) and density plot (right) of one predator fish to compare daytime (top) and nighttime distributions.

Additional observed behaviors include:

- Schooling/Shoaling
- Predation and Predator Avoidance

How are these observations possible?



If tag detections are uniformly spaced with a high level of precision, these detections can be used to assess fish behavior. Single hydrophone detection data can indicate that a predation event has occurred when a tag is shed (defecated) within the detection range. If multiple hydrophones are deployed to provide fine-scale 2D or 3D fish track data, then sudden behavioral changes or quantifiable patterns of swimming behavior can be used to infer predation events. High-resolution fish track data provides valuable information that can aid in distinguishing migrating smolt behavior and the behavior of predatory fish that have previously consumed a tagged smolt. The decision rules used to interpret tagged fish behavioral characteristics should always be considered and developed in context with concurrent environmental conditions.

Data courtesy of California Department of Water Resources, Washington Department of Transportation and US Fish and Wildlife Service.