Testing the Effects of Tag Interference

Acoustic Tag Experiment Report (March 2013)

Abstract

Acoustic technology is an expanding field of research tools being used around the world to monitor various marine animals. In the current study, acoustic tags were tested to help determine the effects of tag interference. Tag interference is when the transmissions from separate acoustic tags occur at the same time and inhibit the recording of accurate data. Three experiments were conducted. The first experiment was done to test the effects of different cases on the acoustic strength of the tags. The second experiment was a preliminary study on the effects of acoustic tag collisions, which led to an improved second version with the same question. The case study tested the difference in acoustic strength from tags in each of the four types of cases: none, small case with holes, small case without holes, and large case. Tags were placed in each of the four case types and placed inside a mesh bag about one meter away from the hydrophone, with both objects being roughly one meter deep, and monitored for one hour. After three trials, the tags with no cases seemed to exhibit a higher overall average of acoustic strength then the other case types. The first collision experiment used 4, 8, and 16 tags that were grouped together in one bag approximately one meter from the hydrophone and monitored for one hour per group. Results showed some unexpected patterns and required more data to show significant difference, which led to the third experiment. All of the uncontrolled variables that were discovered were eliminated in the second version of this experiment. A second collision experiment was done using 1, 2, 4, 8, and 12 tags that were positioned in a row adjacent to the hydrophone, around 2 meters deep and monitored for 24-48 hours per group. In an attempt to eliminate the "donut effect", tags were placed approximately 4 meters away from the hydrophone. Data showed a strong negative correlation of the proportion of received pings over the expected pings with increasing tags.

Introduction

Acoustic monitoring technology has been gaining popularity in scientific research in recent years. The study of collision rates of acoustic tags are important because they are likely to occur in situations when tagging species in populations with high densities (i.e. schooling fish), or monitoring areas with multiple transmitters. VEMCO VR2W Positioning System (VPS) involves the use of at least three acoustic receivers set up around an area with a reference tag in the center. Depending on the size of the area being monitored, there may be more than one reference tag being used. This would mean that there would always be at least two tags in the same area sending signals to the receivers. Having multiple tags in these areas would promote certain circumstances where collisions are likely to be more frequent. Small areas with high densities of fish also pose a threat to the monitoring of acoustic tags. For example, if a tagged fish were to live in a high density population in a small area (i.e. schooling fish), there would be a high chance of the signal being blocked by another fish.

There are different types and sizes of tags and receivers now available to researchers. Some companies that sell these products include: VEMCO, Lotek, Advanced Telemetry Systems, and Hydroacoustic Technology, Inc. It is important to be very knowledgeable about the animal and environment in which you are trying to study in order to use the most appropriate tag. The size of the animal will help to determine the appropriate size of tag to use in order to limit the effects on the species being studied (i.e. behavior). Understanding the type of environment is also important because changes in salinity, temperature, and depth can alter sound properties. Each transmitter is programmed with a unique coded ping rate, which are the identifying signals for each tag. Ping rates are a series of periodic transmissions ("pings") with specific pauses between them. Any interruption between these intervals (i.e. two tags transmitting at the same time) will lead to either a loss of the signal or false identification number (Lacroix and Voegeli, 2000).

Background noise, solid objects, and the position of the receiver in the water have effects on the ability to detect the transmitters (Clements et al. 2005). Receivers too close to the surface can also be affected by wave action, air bubbles, and boat traffic (Clements et al. 2005). Hard objects/substrate can negatively affect the detection range of the transmitter(s) by acting like sound barriers (Huepel et al. 2006). Sound barriers are structures that reduce the source noise intensity and therefore inhibit the detecting range of the tag.

Methods

The case experiment was conducted to test the effects of various sizes of cases on the acoustic strength of the tags. Four tags were used in this experiment, one tag was left without a case, and the other three tags were placed into the other types of cases made out of PVC pipe (small case with holes, small case without holes, and large case). Once placed inside their cases, the tags were then placed in mesh bag about 1 meter away from the hydrophone, with both objects being roughly 1 meter deep. Acoustic strength of the tag was monitored for one hour using the VR100 receiver. After one hour, the bag was shaken to randomly orient the transmitters, and monitored for another hour. All of the tags were then placed, without any cases, back into the mesh bag to be monitored for another hour.

The first tag collision experiment was conducted to test the effects of tag interference. Four tags without cases were placed into a mesh bag, ~1m deep and ~1m away from the hydrophone (also ~1m deep) attached to a VR100 receiver and monitored for one hour. After the first hour, an additional four tags were added and monitored for one hour. After the second hour, another eight tags were added and monitored for one hour. In order to test if the tag orientation might play a factor in the signal strength, the bag was shaken every time additional tags were placed inside.

Due to the results of the first collision experiment, a second collision experiment was conducted to test the effects of tag interference. This second collision experiment was conducted because the resulting data from the first tag collision experiment showed signs of some uncontrolled variables, and did not provide large enough samples sizes to show statistical significance differences. For this experiment a "T-shaped" object constructed out of PVC (~2m x 3m) and was oriented like an upside-down "T", placed ~2m deep and ~4m away from the hydrophone (also ~2m deep). This set-up was designed to allow a clear line-of-sight for each tag to the hydrophone to avoid the blocking of tag signals, which may have been an issue in the first collision experiment. Acoustic tags were individually placed inside the cut-off finger sections of cotton gloves because this was believed to be an acoustically transparent container, unlike the PVC cases used in the case experiment. One tag was originally attached to the PVC object and monitored for ~24 hours. Then another tag was attached and monitored for another ~48 hours. Two additional tags were then added and monitored for ~48 hours. This process was repeated again for eight and twelve tags that were each monitored for ~24 hours.

All data analysis was conducted using R Studio. For the case experiment, the acoustic strength of each tag was recorded for each trial and plotted based on the frequency of transmissions for each decibel. Each tag had its acoustic strength data averaged to get the mean acoustic strength for each type of case. A Welch's Two Sample t-test was then performed for each case type in each trial to determine statistical significance. For the two collision experiments, the total number of pings received during each experiment was divided by the total number of transmissions received within each monitoring period to obtain the proportion of pings received. The transmissions received from each tag were based on their ping intervals. A linear regression was then plotted on top of the data in order to determine the amount of variance.

Results

In the first trial of the case experiment, all the tags in the cases had similar mean acoustic strength, but the tag with no case gave the highest average acoustic strength (Fig.1). The tag with no case showed statistical significant differences when compared to the tag in the small case without holes ($P=0.00341$), the tag in the small case with holes ($P=0.0005183$), and the tag in the large case ($P=0.003402$).

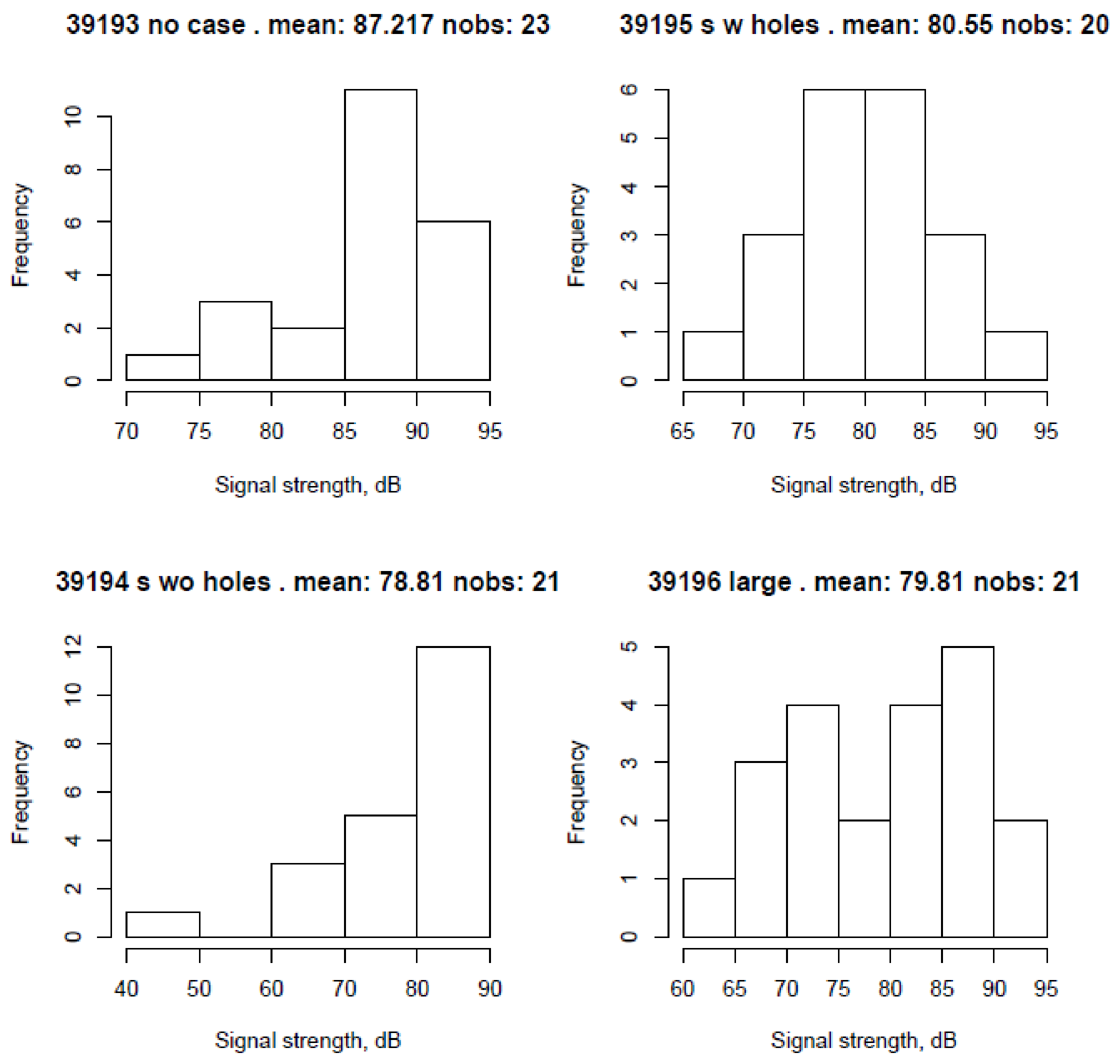

Fig. 1: Acoustic strength of tags with various cases at 1m depth and 1m from hydrophone

Data from the second experiment showed that the tag in the small case with holes recorded the highest average acoustic strength (Fig.2). The results also showed that the tag in the small case without holes had weakest acoustic strength and lowest amount of observations (Fig.2). No statistically significant differences were observed between any of these tags.

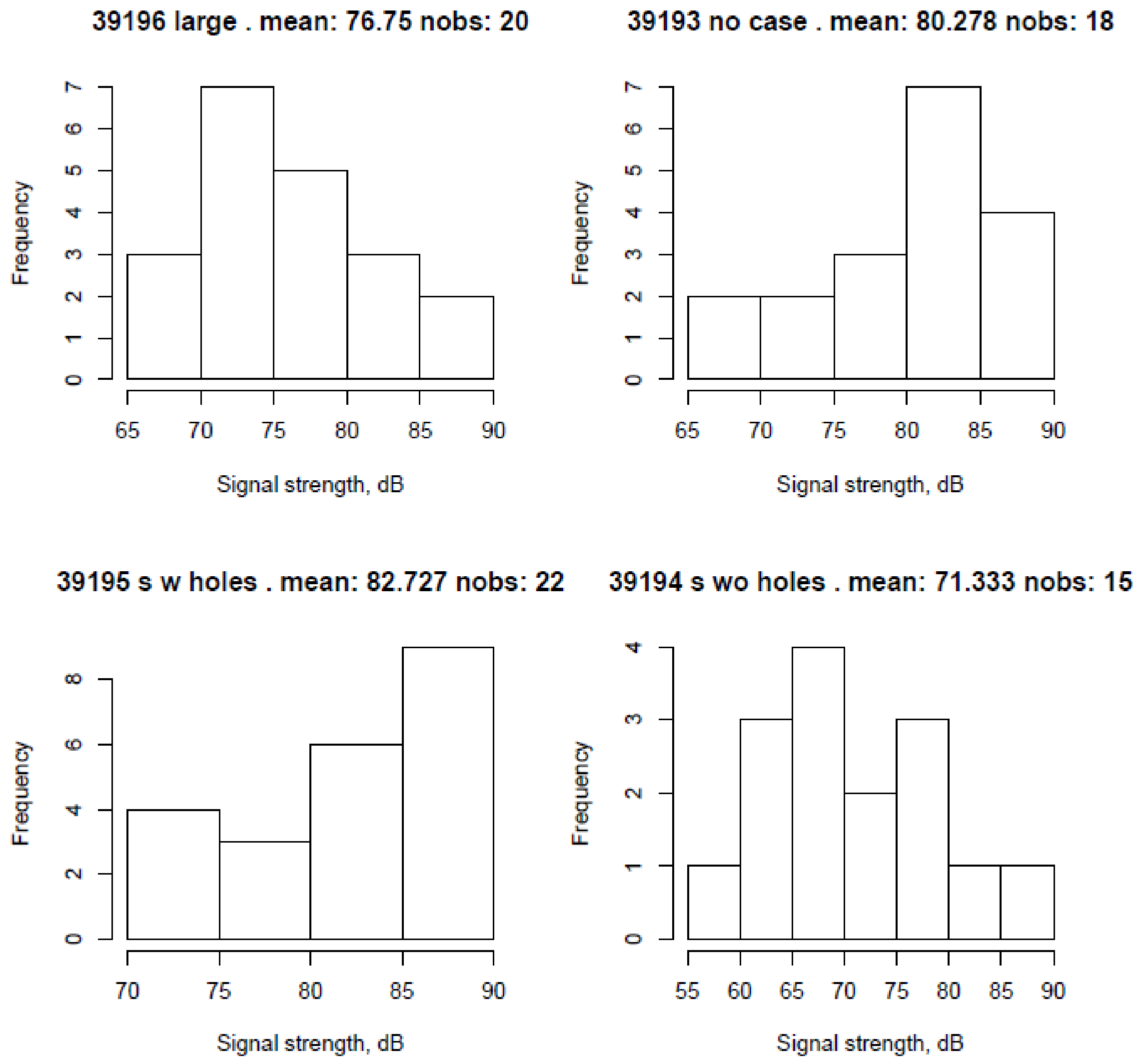

Fig. 2: Acoustic strength of tags with various cases at 1m depth and 1m from hydrophone

Data from the third trial showed that all the tags had similar average acoustic strength except for one tag, 39196 (Fig.3). No statistically significant differences were observed between any of these tags.

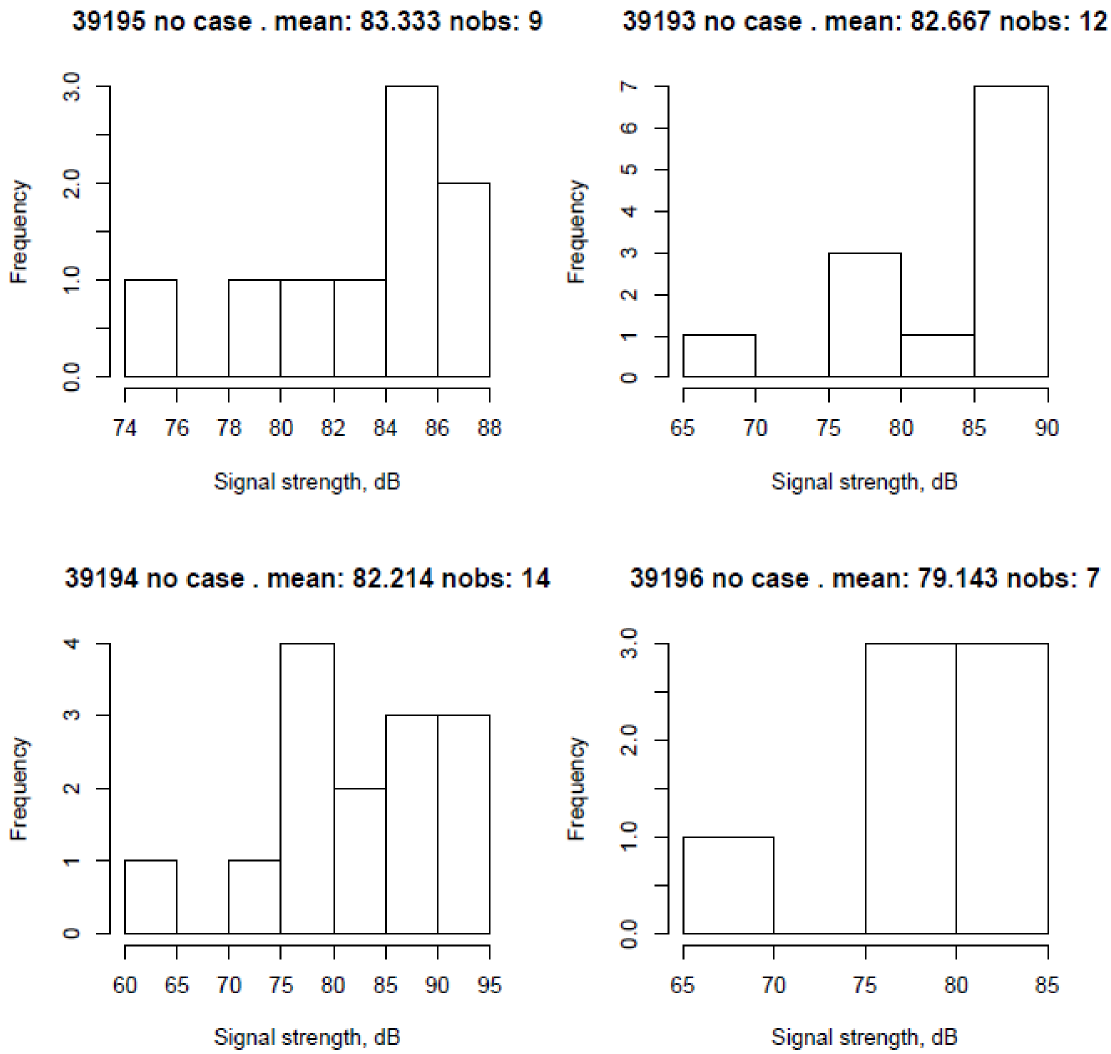

Fig. 3: Acoustic strength of tags with no cases at 1m depth and 1m from hydrophone

Results from the first collision experiment revealed a few unexpected errors. For one, the detection of the acoustic tags increased with increasing amounts of tags when comparing 4 tags to 8 tags (Fig.4). However, when the number of tags increased to 16 tags, there was a decline in detection (Fig.4). The resulting amount of data also seemed too small to significantly show any differences (therefore, had relatively large error bars). A linear regression line was plotted with an intercept of 0.734099 (P=0.0749), slope of -0.01725 (P=0.2824), and R-squared value of 0.8158.

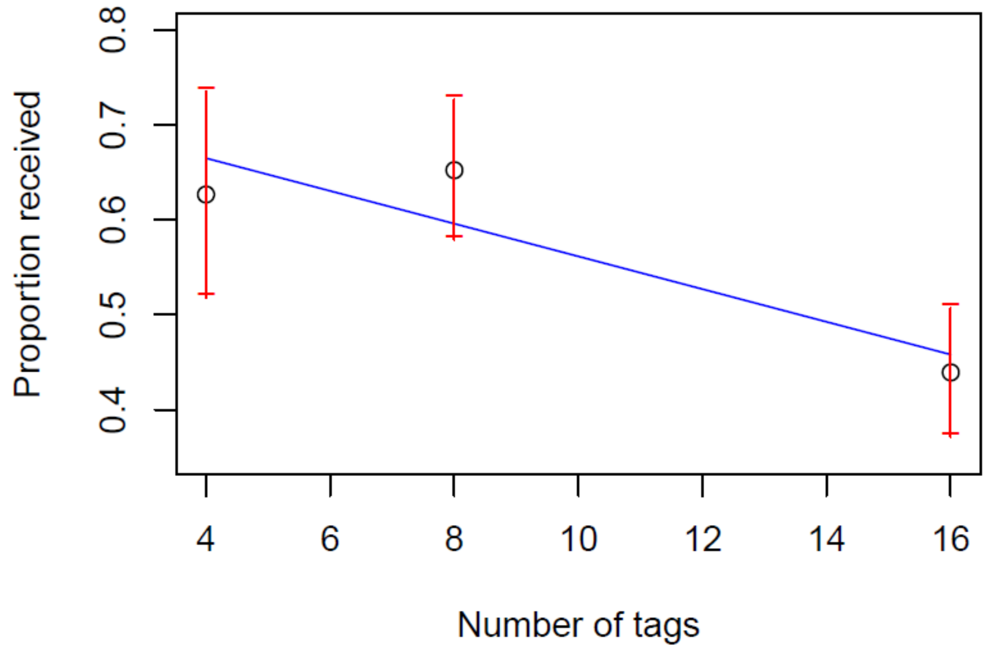

Fig. 4: Proportion of received/expected pings for each group of tags tested

Results from the second collision experiment showed a negative correlation between the number of tags being used and the proportion of pings detected (Fig.5). A linear regression line was plotted with an intercept of 0.793564 (P= 3.68e-05), slope of -0.030516 (P= 0.00202) and R-squared value of 0.9718.

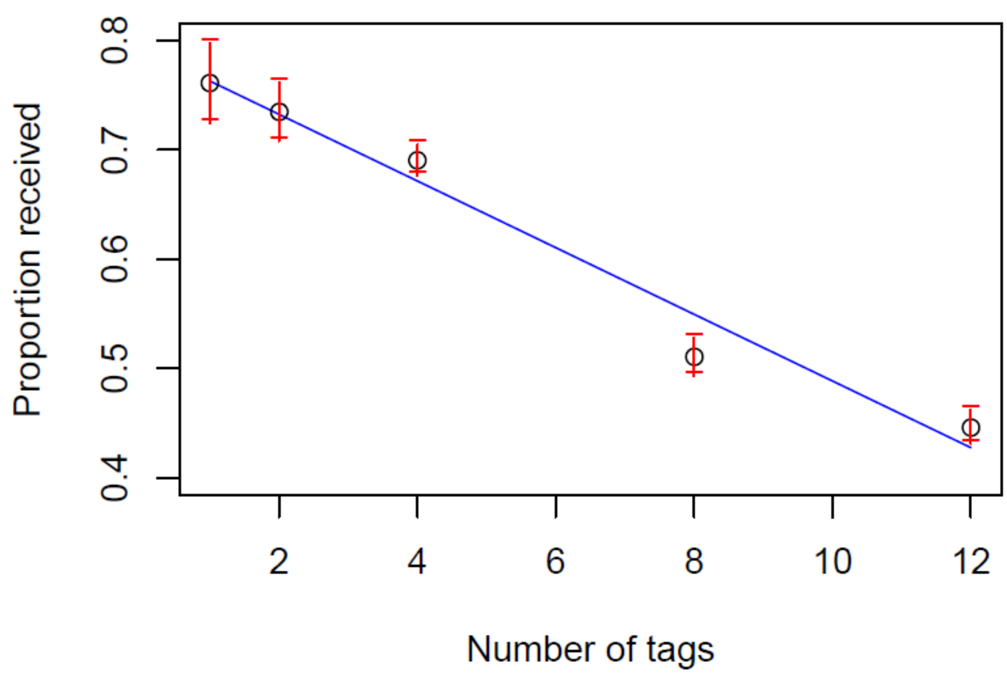

Fig. 5: Proportion of received/expected pings for each group of tags tested

Discussion

This study allowed an insight into the effects of acoustic tag collisions. The resulting data supports the idea that tag interference affects the detection of acoustic tags. According to the data presented, it seems that the more tags being monitored within a close proximity to each other, or within one meter of the hydrophone, the less likely they are to be detected. Therefore, performing VPS studies may not be the best way to monitor acoustically tagged fish species.

Future studies can be done to further explain the unexpected errors found in the collision experiments. One possible explanation for the rise and fall of the proportion of tags received during the first collision experiment could have been due to the "donut effect". The "donut effect" states that if the transmitter and receiver are too close to each other, there is an area where detection probability is low. A rise in the proportion received in the first collision experiment could also have been caused by the small sample size used. The donut effect is also believed to have caused the downward shift of the regression line (from 1 to ~6.5) in the graph from the first experiment and (from 1 to ~0.75) in the graph from the second collision experiment.

It is important to note that different study designs will have different collision probability based on the: scale of study area, number of tags in the water, VPS/non-VPS and use of reference tags, and detection functions.

References

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