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PILE DRIVING AND BIOACOUSTIC IMPACTS ON FISH

How Did We Get Into This Mess? Where Do We Go From Here?
Status of Developing Best Available Science to Improve Decision-Making Processes

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Abstract

How did those of us in the transportation industry suddenly find ourselves in need of knowing about underwater pressure waves and fish barotrauma? On October 17, 1989, a portion of the East Span of the San Francisco Oakland Bay Bridge collapsed. That event was the catalyst for the State of California to institute a comprehensive seismic retrofit program for its bridge structures. The bridge is considered a “vital lifeline structure” to San Francisco. Therefore, the bridge was to be designed to withstand the maximum expected credible quake with a design-life of 150 years. The criticality of the structure, the design life, and the soil conditions in San Francisco Bay precipitated the need for an innovative foundation design that was the nexus to use steel piles as the preferred structural support material. Ultimately, there was no structural alternative. When we began driving the steel piles, we realized that underwater pressure waves were being generated that caused stunning and even death to fish near the pile.

Pressure waves are generated when the hammer strikes the pile, imparting a flexural wave that moves down the pile at approximately 5000 feet per second. As the wave does this, it interacts with the air, creating a localized pressure perturbation, resulting in airborne noise. It then moves through the water column creating compressional waves. This results in what we refer to as a hydroacoustic pulse. Finally, the energy moves down into the more-resistant substrate, where it is dissipated through the physical displacement of soil particles. A wave travels down, then back up, and it continues to reverberate until all of the energy has been dissipated, into the air, water, and soil.

Our efforts to develop a better understanding of the acoustic properties of pile driving and its effects on fish began with examining the findings from past research for their relevance and applicability while looking at a variety of wave forms. The U.S. Army Corp of Engineers, Canada’s Department of Fisheries, the US Navy, and others have done many studies on the effects of explosive blasts on fish. There is a relatively small, but high-quality, body of literature that exists for effects of long-term continuous noise exposure on fish, such as that found in active sonar arrays. There is almost no information on pile driving impacts.

We have also been designing and testing various noise-attenuation technologies. The bubble-tree attenuation device used to surround piles being driven for the Benicia-Martinez Bridge Project successfully reduced peak noise levels to an approximate 20m radius around the pile. This equated to a 99.8% reduction in radiated energy compared to an unattenuated pile.

What are some of the lessons we have learned so far? First, one needs to understand the ramifications of permit terms and conditions for these types of projects. These have to be meaningful and measurable criteria. They need to be biologically relevant and technologically possible conditions. For instance, underwater noise-monitoring equipment needs to be able to measure the target frequencies committed to within the permit. Second, one needs to develop and follow monitoring protocols with specific objectives and study controls. In other words, don’t go out and collect a bunch of data and then try and make something of it. Third, one needs to obtain incidental take authorization to avoid unanticipated work stoppages. Last and most important, avoid jeopardy and avoid and minimize the incidental effect of take to the extent practicable.

What else have we learned? This is a highly complex issue, and we need to be very careful to ensure we base decisions on credible and relevant information. Just because it is in print does not mean it is useful, credible, or relevant. As the Endangered Species Act (ESA) clearly states: “The best available information is to be used in the implementation of the ESA and this information must be reliable, credible, and represent the best scientific and commercial data available.”

We soon realized other states and industries were struggling similarly with this issue and that by working together we could be more effective in our efforts. Therefore, two years ago we formed the Fisheries and Hydroacoustic Working Group. The three key goals of the Fisheries and Hydroacoustic Working Group are to summarize: 1) what we currently know (what is the best available science); 2) what we need to know (define future research needs); and, 3) what is the best application of current information for consistent interim standards. As new information is developed, the cycle repeats itself, and we will continue to update our summary of current understanding, re-evaluate further research needs, and re-evaluate and possibly modify noise-criteria standards based on what we have learned. In support of this effort, Caltrans funded preparation of the report titled “Effects of Sound on Fish” by Mardi C. Hastings, Ph.D., and Arthur N. Popper, Ph.D., that was completed in January 2005. The final report constitutes a comprehensive literature review and analysis of relevant research, recommendations for preliminary guidance, areas of uncertainty, and recommended research.
Caltrans also submitted a proposal to the Transportation Research Board, National Cooperative Highway Research Program to fund a national research study to evaluate hydroacoustic impacts on fish from pile installations. That proposal was accepted and is underway. It is Project 25-28, Hydroacoustic Impacts on Fish from Pile Installation.

The Federal Highway Administration has also sponsored a pooled-fund project titled “Structural Acoustic Analysis of Piles.” The study's goals are to develop and validate models of sound fields and the effects of attenuation systems, to develop and validate acoustical source models of pile driving, to synthesize information from this project with other pertinent research, and to develop a guidance document for practitioners.

The three most recent efforts that Caltrans has underway are: 1) the development of an Interim Guidance Manual that identifies procedures for assessing and mitigating effects of pile driving sound on fish; 2) the development of an underwater sound-pressure compendium; and, 3) development of a methodology for measuring and reporting underwater sound pressure.

**Biographical Sketch:** Deborah McKee is a senior environmental planner, aquatic resource biologist for the California Department of Transportation (Caltrans). Ms. McKee oversees research, regulatory compliance, and inter-agency coordination for aquatic resources including fisheries bioacoustics.