**FILE MEMORANDUM** F/NWR-5

**DATE:** 11/11/2014

**FROM:** Trevor Conder NOAA Fisheries

**TO:** FPOM; Noise and Vibration Task Group

**SUBJECT:** Noise and vibration from construction activities occurring near fishways and potential for impacts to fish

INTRODUCTION

During the fish passage season, all construction activities occurring near or on fishways at Bonneville, The Dalles, and John Day Dams are regionally coordinated through the FPOM process as stated in the Fish Passage Plan. These activities are coordinated to notify managers of ongoing construction issues, and to allow them an opportunity to provide input so impacts to ESA listed species are minimized. In July of 2014, it was identified at FPOM that McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams do not have a requirement for construction coordination written within the FPP. At the August FPOM draft change forms adding similar construction language for these five dams were submitted for approval. At that meeting NWW did not approve the change forms and requested a separate task group to review additional information. This memo highlights additional information supporting that noise and vibration caused by construction near ladders can elicit negative behavioral responses in salmonids which can impact overall survival at the individual and population levels. This information supports a conservative and reasonable argument that NWW should coordinate with regional managers through FPOM when construction activities occur on or near fishways during the fish passage season.

SENSING SOUND AND VIBRATION

Sound can be defined as vibrations that travel through a medium that can be percieved when they reach an animal's ear. Salmonids detect sound or vibration with the inner ear, lateral line, and swim bladder. Fish are adapted to sense sonic vibrations and have receptors in their tissue to transform these signals into nerve impulses used for activities like detecting prey, avoiding predators, and communication. Hearing in salmonids is primarily the responsibility of the inner ear which contains the otoliths and sensory hair cells (Helfman et al. 1997). Sound provides a fish with a three-dimensional “view” where they use hearing to learn about their environment. Damage resulting to an impairment of hearing can reduce a fish’s ability to successfully perceive and interact with its environment. Fish can also detect low-frequency sounds (<100 Hz) in the water when sound waves displace neuromasts of the lateral line system (Bleckmann 1993). Salmonids rely on sound and vibrations to establish orientation, maintain equilibrium, and interpret their surroundings. Decreased sensitivity to sound could alter behavior and decrease survival probability (Oxman et al. 2007).

IMPACTS OF SOUND AND MECHANICAL VIBRATION

The available literature indicates human generated sounds can affect the physiology, behavior, and fitness of fish depending on the intensity, frequency, and proximity of the sound. Depending on these variables, a fishes response to sound might range from no change in behavior, to awareness, startle response (Wardle et al.2001), larger movement patterns (Slotte et al.2004), and avoidance (Bell 1991). In addition to behavioral responses, sound pressure occurring above a fish’s hearing threshold has been demonstrated to lead to hearing loss and associated stress responses that may reduce fitness (Hastings *et al.* 1996). In more extreme cases, immediate death has been observed where fish were in close proximity to high intensity sound such as from pile driving and seismic air guns; however, typical construction activities occurring near ladders are not expected to cause immediate death. Depending on the level of sound and behavioral response, there may be no real impact on individuals, or there might be substantial changes (e.g. movement from spawning areas) to affect the survival of a population (Hastings 2009).

SALMONID SENSITIVITY TO SOUND

Fish may be affected by sound waves and the resulting pressure, and may avoid sudden noise or movement, but ignore the same noise or vibration if it continues over a long period of time (Bell 1991). Sound amplitude and frequency fluctuations have been shown to increase stress responses in contrast to continuous noise of the same intensity (Wysocki et al. 2005). Salmonids are sensitive to changes in sound and vibration within the range of 5-1000Hz (Bell 1991). Chinook salmon were most sensitive to sound within the range of 100-300Hz where Oxman et al. (2007) demonstrate that Chinook salmon respond to sounds at 105dB and greater. Mueler et al. (1998) found that Chinook salmon startle in response to low frequency sound in the 7 to 14 Hz range and at 150 Hz to high intensity sound. The available information indicates salmonids perceive sound and can demonstrate behavioral responses to sounds in water if the sounds are within their frequency and amplitude threshold.

SOUND AND VIBRATION IN WATER

The amount of sound and vibration that is transmitted between mediums is an important consideration in understanding if fish are impacted by construction activities. Because water is much denser than air, sound waves produced in air are mostly reflected off the water surface back into air, resulting in a weak intensity of sound absorbed into the water. Although actual materials are not perfect reflectors, the acoustic impedance match between air and water is so poor that very little energy goes into sound waves in the denser medium. Because the transmission of sound from air to water is so poor, airborne sounds are not considered a major concern for fish passage.

While airborne sound is not a major concern for fish passage, construction activities that transmit sound and vibrations into solids, such as using a jackhammer to remove concrete, can impact fish if the construction activity is in close proximity to a fishway. Sound and vibrations can be transferred and perceived by migrating fish since sound energy can transfer from a solid to a liquid (Lamb 1925). The sound waves that penetrate into a liquid can travel fast and far due to water’s relatively low acoustic impedance. If the vibration produced by construction activity travels into water and is perceived by fish in a nearby fishway, negative effects such as avoidance, fright response, or hearing loss may occur.

EVIDENCE OF AVOIDANCE in FCRPS

Avoidance is defined as a reluctance or refusal of fish to move from one place or situation to another (Bell 1991). Studies evaluating the relationship between construction and salmon behavior within the FCRPS are minimal, but there is evidence that construction activities have altered behavior of salmonids within the FCRPS. In 2002, researchers used radio-telemetry to evaluate the effects of construction on salmon and steelhead passage at Lower Monumental Dam. While significant delay was not an issue, the researchers found evidence that salmon and steelhead were avoiding entrances proximal to the construction activity, with increasing usage of entrances further from construction activities. These researchers concluded that shifts in ladder usage were likely attributable to construction since there were no other operational differences to account for the change (Jepson et al. 2004). While the biological impacts in this case were likely minimal, it does show that construction activities can impact salmonid behavior. If these types of avoidance behaviors occurred within a single fish ladder, biologically significant impacts would likely result.

CONCLUSION

From the information presented in this memo, it is clear that salmonids can perceive sound and vibration. It is also clear that construction activities can produce sound and vibration which can be transmitted to water through a solid material. The available information indicates salmon behavior can be affected in negative ways, and could lead to an overall reduction in fitness if sound and vibrations are perceived by salmonids depending on the frequency, duration, and intensity of the sound or vibration. This evidence supports a conservative approach to conducting construction activities near fish ladders within the fish passage season. This information does not indicate that construction shall not occur, rather that it should be coordinated with regional fish mangers to develop the most benign and reasonable method to get the work completed without negatively impacting ESA listed salmonids.

REFERENCES

Bell, M. C. 1991. Fisheries handbook of Engineering Requirements and Biological Criteria. U.S. Army Corps of Engineers.

Bleckmann, H. 1993. Role of the lateral line in fish behavior. The Behavior of teleost fishes, 2d ed. T.J. Pitcher, 201-246. London: Chapman and Hall.

Helfman G. S. and Coauthors. 1997. The Diversity of Fishes. 69-72. Blackwell Science, Inc.

Jepson M. A., Joosten D.C. Moser M. L. and Peery C.A. 2004 An Evaluation of the Effects of Spill Basin Drilling on Salmon and Steelhead Passage at Lower Monumental Dam in 2002 using Radio-telemetry. Report to U.S. Army Corps of Engineers Walla Walla District.

Lamb H., 1925. *The Dynamical Theory of Sound*, 2nd ed. London: Edward Arnold and Co., 1925. Chapter VI.

Mueller, Robert P., Duane A. Neitzel, William V. Mavros, 1998, Evaluation of Low and High Frequency Sound for Enhancing Fish Screening Facilities, to Protect Outmigrating Salmonids, (DOE/BP-62611-13) to Bonneville Power Administration, Portland, OR, Contract No. DE-AI79-86BP62611, Project No. 86-118, 38 p. (BPA Report DOE/BP-62611-13)

Oxman D. S. and Coauthors. 2007. The effect of vaterite deposition on sound reception, otolith morphology and inner ear sensory epithelia in hatchery-reared Chinook salmon *(Oncorhynchus tshawytscha).* Can. J. Fish. Aqual. Sci 64. 1469-1478.

Wysocki L. E. and Coauthors. 2005. Ship noise and cortisol secretion in European freshwater fishes. Biological Conservation 128. 501-508.

More cited references to be added