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Proposed by DFO

PROJECT TITLE: *Evaluation of the potential impacts of seismic surveys on the behaviour and auditory physiology of fish in the Mackenzie River.*

PROJECT MANAGERS: Eric Gyselman[1], Arthur N. Popper[2]

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PRIORITY AREA: Onshore and Offshore Mackenzie Delta and/or lower Mackenzie River

GEOGRAPHIC AREA: NWT

OBJECTIVES:
This proposal contains two interrelated subprojects. The objectives for each subproject, as well as the rationale and work plan to accomplish each objective, is described below.

1) To measure the behavioural responses of fish in the Mackenzie River to varying intensities of seismic sound generate by an air gun array.

2) To assess the impacts of air gun sounds on the auditory system of fishes.

RATIONALE

Introduction

The development of oil and gas in the Mackenzie Delta and Mackenzie Valley will require additional seismic surveying to refine the location and extent of reserves. One method that has been proposed to acquire additional geological information is the use of airgun arrays towed behind survey ships in the Mackenzie River and its larger tributaries. This approach is viewed by some of the exploration companies as a cost effective technique that minimizes the environmental impact when compared to more conventional land-based surveys. However, the impacts of seismic sound sources on the biota in rivers, and particularly Arctic rivers, are not well understood. The inference of information collected in the marine environment is not directly applicable to rivers because of the confining characteristics of the riverbed. Therefore, shifts in heart rate, and shifts in the electrical resistance of the skin and muscle tension (Davis et al., 1955).

Clearly, loss of hearing or the masking of hearing, whether permanent or temporary, may have a profound impact on the daily life and survival of an organism. Sound plays a major role in the lives of almost all (if not all) vertebrates, and many invertebrates as well, for communication and to enable animals to gain an overall sense of the world around them (see Fay and Popper, 2000).

Although far less is known about the effects of anthropogenic sounds on fishes than on terrestrial or marine mammals, there is a small but growing body of peer-reviewed literature demonstrating that such sounds can destroy the sensory cells in fish ears and that long-term exposure to such sounds will cause temporary, and possibly permanent, loss of hearing (Enger, 1981; Hastings et al., 1996; McCauley et al, 2003; Popper, 2003; Smith et al., 2003).

One of the better-known anthropogenic sound sources is the seismic air gun used by geologists looking for petroleum under the bottom of an aquatic environment. In a recent study, McCauley et al. (2003) investigated the effects of exposure to air gun sounds in the pink snapper (*Pagrus auratus*), a fish found in Australian waters. Fish were placed in a large cage in a large bay and exposed to air guns over several hours. The fish were allowed to survive for different intervals after exposure, and the ears were then examined for any damage resulting from exposure to the sound. The results clearly showed that there was extensive damage to the sensory cells of the ear and that the level of damage increased the longer the fish were allowed to survive post-exposure, up to at least 58 days (the maximum survival interval described).

It is important to note that this study was done only on a single marine species and that the fish were caged and so could not escape the intense sound. However, the study was significant in that it demonstrated that the sounds from seismic air guns can have a substantial effect on the ears (and thus the hearing) of a marine species. Although it is likely that some fish species would immediately leave the area of an air gun study, there are many species of fish that do not move when presented with a fright stimulus, and it is likely that such species could have profound damage to their ears and hearing.

Several studies have also demonstrated changes in the hearing ability of fish that may be temporary or permanent. The presentation of sounds for a few minutes to a few hours will result in a temporary loss of hearing in a number of different species (e.g., Popper and Clarke, 1976; Scholik and Yan, 2002; Smith et al., 2003). In each case, hearing sensitivity was substantially reduced (compared to that in control animals) when it was measured immediately after exposure to loud sounds but returned to normal over time. Most recently, Smith et al. (2003) found that goldfish took over two weeks to return to normal hearing after a three-week exposure to only moderate sound levels (170 dB re: 1 μPa). Scholik and Yan (2001) found that fathead minnows did not recover to control levels even as long as 14 days after the termination of 24 hours of noise exposure.

Previous studies have shown that a seismic air gun can cause damage to the ears of fishes (McCauley et al., 2003). While that study provides the only data relevant to the concerns with regard to the source proposed by WesternGeco, it is important to note that the fish used by McCauley et al. were exposed to a longer sound regime than for the single pass to take place in the Mackenzie River. At the same time, however, much lower sound levels for short exposure times also cause changes in hearing capabilities (see above). Since it is likely that the effects of sound are related both to duration of exposure and the intensity of exposure, it is possible that a very short exposure to a very loud sound could have the same effect on

A scientific-grade acoustic sounder installed on a survey launch will be used to measure the precise location of individual fish at a defined site in the Mackenzie River and then to track the movements of these fish at different sound source levels. This will be done by anchoring the launch a various distances from the sound source and tracking the movements of individual fish using contemporary target tracking software. As many experiments will be done during the time window available to see if the behaviour is consistent at different locations and different times of the day.

Small samples of fish (n<50) will need to be caught, identified, and measured in order to determine the species and size distribution that are being observed acoustically The results from these measurements will then be mapped to create a predictive model of fish behaviour that can be used to assist in the design of future seismic surveys.

Fisheries and Oceans Canada will have an acoustics survey launch in Inuvik during the summer of 2004 to conduct components of the Beaufort Sea Habitat Mapping Program. This launch will be able to conduct acoustic studies that address the shortcomings arising from the results of the IMG-Golder study. The approach will follow that used for similar studies undertaken under the auspices of the International Council on the Exploration of the Sea (ICES) that measured vessel avoidance behaviour for research vessels. No single preconceived model will be presumed. Rather, the project will utilize a protocol that will enable direct measurement of the behaviour of individual fish as the seismic survey vessel approaches.

Objective 2)

Overview

Work will be conducted by Dr. Arthur N. Popper in collaboration with Dr. David Mann. Drs. Popper and Mann have extensive experience in conducting studies of the fish auditory system and hearing, and have collaborated on a number of highly successful projects that have successfully used and reported on all of the methods described here (e.g., Mann et al. 2001; Platt et al. in press). This project will examine the effects of exposure to the output of a seismic air gun on the auditory system of whitefish and one additional species to be chosen at a later date. The study will investigate hearing capabilities of the fish after exposure to the air gun and specifically determine: (a) if there is hearing loss that lasts for more than a few minutes post-exposure; (b) the duration of any hearing loss; (c) the time course of recovery from hearing loss; and (d) whether there is damage to the ear associated with any long-term hearing loss.

The basic work plan will be to expose caged fish to the output of the air gun array at a sound level to be determined later. Immediately after exposure the fish will be removed from the cage and their hearing will be assessed using the auditory brainstem response (ABR), a relatively rapid measure of hearing capabilities. We will continue to test fish on a regular basis for two to three days post exposure to determine if there are changes in hearing ability as compared to non-exposed controls.

Specific Work Plan

Animals will be placed in a cage and exposed to a predetermined number of seismic sounds. The basic paradigm to be used is described herein, but the specific approach in terms of when animals will be tested is likely to vary and will depend very much on the timing of the exposure to sounds using the airgun array and the logistics of the experiments. These can only failure, lack of good holding facilities for fish and their loss before testing, and difficulties in recording ABR from the fish.

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