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TITLE: An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes

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ABSTRACT:

Fishes use a variety of sensory systems to learn about their environments and to communicate. Of the various senses, hearing plays a particularly important role for fishes in providing information, often from great distances, from all around these animals. This information is in all three spatial dimensions, often overcoming the limitations of other senses such as vision, touch, taste and smell. Sound is used for communication between fishes, mating behaviour, the detection of prey and predators, orientation and migration and habitat selection. Thus, anything that interferes with the ability of a fish to detect and respond to biologically relevant sounds can decrease survival and fitness of individuals and populations. Since the onset of the Industrial Revolution, there has been a growing increase in the noise that humans put into the water. These anthropogenic sounds are from a wide range of sources that include shipping, sonars, construction activities (e.g., wind farms, harbours), trawling, dredging and exploration for oil and gas. Anthropogenic sounds may be sufficiently intense to result in death or mortal injury. However, anthropogenic sounds at lower levels may result in temporary hearing impairment, physiological changes including stress effects, changes in behaviour or the masking of biologically important sounds. The intent of this paper is to review the potential effects of anthropogenic sounds upon fishes, the potential consequences for populations and ecosystems and the need to develop sound exposure criteria and relevant regulations. However, assuming that many readers may not have a background in fish bioacoustics, the paper first provides information on underwater acoustics, with a focus on introducing the very important concept of particle motion, the primary acoustic stimulus for all fishes, including elasmobranchs. The paper then provides background material on fish hearing, sound production and acoustic behaviour. This is followed by an overview of what is known about effects of anthropogenic sounds on fishes and considers the current guidelines and criteria being used world-wide to assess potential effects on fishes. Most importantly, the paper provides the most complete summary of the effects of anthropogenic noise on fishes to date. It is also made clear that there are currently so many information gaps that it is almost impossible to reach clear conclusions on the nature and levels of anthropogenic sounds that have potential to cause changes in animal behaviour, or even result in physical harm. Further research is required on the responses of a range of fish species to different sound sources, under different conditions. There is a need both to examine the immediate effects of sound exposure and the longer-term effects, in terms of fitness and likely impacts upon populations.

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