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H. E. Cormack

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Introduction

Ultrasonic waves have been considered a possible means of controlling sea lamprey in the Great Lakes. The term "ultrasonic" is applied to sound waves of a frequency above the auditory level, that is, ranging from 16,000 cycles per second up, although it has often been erroneously applied to lower frequencies. Before undertaking any experimental work, a survey was made of most of the literature dealing with the effects of ultrasonic waves on biological material. Very little work has been done using sound waves as a mass killer of animals. The following report is based on this survey.

Biological Effects of Ultrasound

In order to get any effects on biological material several points have to be considered. They are: the frequency of the sound wave, the intensity of the sound, and the time of exposure.

There are both low and high frequency sound waves. Low frequencies start just below the level of human hearing at 12 cycles per second, and go up to 16,000 cycles, which is approximately the upper limit of hearing. Low frequency sound waves will not damage tissue but were considered as a means of attracting or repelling lamprey. Information available indicates little or no effect of low frequency sound waves on the behaviour of fish or lamprey. Thus, Burner and Moore (1953) found that attempts to guide small fish by the use of underwater sound produced by low frequency sources were not successful. After an initial response, the fish paid no attention whatsoever to the sound. Moore and Newman (1956) tried to guide young salmon away from dams and found no reaction, or very little, to the sound. Porpoises have been found to be irritated by sound waves underwater (Kellog and Kohler, 1952) and tuna are attracted (Pacific Fisherman 1952). In Japan, Miyosi (1940) found that fish were not attracted by sound; on the other hand, Moulton (1956) found that the sea robin responded positively to sounds. Moorhouse (1933) tested various fish such as the perch, flounder, rock cod and dogfish. He discovered that only the perch responded and this was an avoidance reaction. Parker (1912) found in his experiments that some fish were attracted and some repelled by sound, while other fish did not give any reaction.

High frequency sound waves (16,000 cycles per second and up) have been used to kill fish and will damage tissue. Chambers and Harvey (1931), Gaines (1932), and Wood and Loomis (1927) killed small fish and tadpoles using unfocussed waves of a frequency of 300,000 cycles per second.

Some early experiments which were done with material to be treated placed directly on the face of the transducing crystal resulted in very little damage (Harvey and Loomis, 1928; Harvey, Harvey and Loomis, 1928). Experiments on specimens in air showed that the subject had to be five to six centimeters away from the sound source before a lethal effect could occur.

Amazing things can be done with focussed sound beams, especially in the field of neurosurgery. A compound transducer head which will concentrate several sound beams can be focussed to damage a particular part of the brain without harming intervening tissue (Barnard, Fry, Fry and Brennan, 1956). Lenses and reflectors will also focus sound waves (Fox and Griffing 1949; Crawford 1955). Distance, however, is still critical. Cats and rats treated with focussed ultrasonic waves were only 6.4 centimeters from the source (Fry 1958).

Cavitation bubbles are a phenomenon associated with the beaming of high frequency sound waves in a liquid medium. When they break there is a force known as "water hammer" which is considered the cause of much damage, both to metal and glass (Gaines 1932) and tissue (Chambers and Gaines 1932; Harvey 1930). Chambers and Harvey in 1932 found skeletal muscles could be damaged with ultrasonic waves, apparently a result of "internal cavitation". Smith (1935) has studied the destructive effects of cavitation bubbles.

The exact cause of tissue damage has been debated by many authors. Some feel that biological effects can occur even when cavitation is suppressed (Dunn 1958; Fry, Tucker, Fry and Wulff 1951). Others say it is the result of heating (Allen, Frings, Rudnick 1948; Jung 1942). Other authors refute this, and have obtained paralysis in frogs in spite of the elimination of the heating effect (Dunn 1958; Fry, Wulff, Tucker and Fry 1950; Wall, Fry, Stephens, Tucker and Lettvin 1951).

Cavitation bubbles in a liquid will cause attenuation, or a thinning out of the sound waves. Since the bubbles are considered the cause of a certain amount of tissue damage, Horton and Horwood (1957) have discussed the feasibility of preventing cavitation in an attempt to eliminate attenuation. Some work has been done by Laird and Kendig (1951) to determine a correlation between the size of the air bubbles and the degree of attenuation of sound at various frequencies. Carstensen and Foldy (1947) have also studied the effects of bubbles on the propagation of sound waves through a liquid medium. Water temperature also has an effect on sound waves (Markham, Beyer and Lindsay 1951; Teeter 1946; Smith and Beyer 1948).

The exposure time required to kill animals is relatively long. Animals that were killed, either in air or in liquids, were exposed to sound waves for periods of time ranging from three to four minutes up to 25 minutes (Allen, Frings and Rudnick 1948; Chambers and Harvey 1931). Cumulative effects of subparalytic irradiation will produce paralysis (Fry 1958).

Susceptible Tissue

Nervous tissue is most susceptible to sound (Dunn 1958; Fry, Wulff, Tucker and Fry, 1950; Hopwood 1931; Wall, Fry, Stephens, Tucker and Lettvin, 1951). Lynn, Zwemer, Chick and Miller (1943) describe cerebral damage in living animals caused by irradiation of focussed ultrasound. The animals were affected for about 16 hours, after which they once more appeared normal. Wall, Fry, Stephens, Tucker and Lettvin (1951) studied the effects of focussed high frequency sound beams on nerve tissue in the spinal cord. Paralysis, destruction of glial cells and loss of the supporting elements in the nerve cord were a result. In 1958, Fry published a detailed review on the effects of focussed ultrasound on nerve tissue. Destruction of gill filaments, haemolysis of erythrocytes, and damage to skeletal muscles are also a result of irradiation.

All of these effects could be applicable to the lamprey.

Preliminary Studies

Kleerekoper (1958) made a preliminary study of the effects of sound waves on adult lamprey, but found little or no effect on their behaviour. No experiments were done on the larval stages of the lamprey. Since ammocoetes spend many years buried in mud in stream beds, and tremendous power is required to beam ultrasound a few inches into the mud (Kleerekoper 1958), this aspect hardly seems worth investigating. Migrating ammocoetes might be affected by an apparatus that would affect adults, but only if the larvae were in the stream proper and not buried in silt.

Conclusions

This type of problem must be dealt with in the field, and equipment of any type must be designed for ultimate use in the field. This applies to techniques also. In the ideal laboratory environment it may be possible to kill or maim sea lamprey, but techniques which will work in the laboratory will not necessarily be successful when applied outside.

The equipment necessary for transducing high frequency sound waves has been described in detail by Crawford (1955). For underwater sound a quartz or barium titanate crystal is used. A generator to provide power is also needed. Lenses and reflectors for focussing sound waves are needed, and would have to be placed in the stream bed. Compound heads for focussed waves are very cumbersome and require proper housing. Expert maintenance would be required for this expensive equipment and care would have to be taken to avoid damage in seasonal flooding. Lamprey would have to be guided into a certain area, and held there while the sound waves took effect, after cavitation and attenuation had been suppressed.

Taking all of these facts into consideration, the author feels that further experiments on the use of sound waves of high or low frequency as a means of controlling the sea lamprey would not be justified at the present moment.

Acknowledgments

The author wishes to thank Dr. H. L. Moore of the U.S. Department of the Interior, and Dr. W. J. Fry of the University of Illinois for their interest. Dr. P. Macy is thanked for the loan of an annotated bibliography on the effects of sound waves on fish, and related subjects, prepared by Dr. H. L. Moore of the Pacific Salmon Investigations of the U.S. Department of the Interior.

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