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REGIONAL COPPER-NICKEL STUDY:
THE EFFECTS OF NOISE ON WILDLIFE

Minnesota Environmental Quality Board
Regional Copper-Nickel Study

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INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

INTRODUCTION

Noise pollution is the release of unwanted sounds into the environment without regard to their possible adverse effects (Odum, 1971:448). Like other forms of environmental pollution, the impacts of noise pollution were magnified by the beginning of the Industrial Revolution nearly 300 years ago. The rising noise levels associated with the development of more sophisticated means of transport and industrial production were demonstrated as detrimental to man's hearing and well-being. Even as early as 1670, Swedish scientists had reported the prevalence of deafness among coppersmiths and blacksmiths (Groom, 1972).

Although the impacts of noise pollution on man are well-documented (e.g. Kryter, 1972; Miller, 1974), the impacts of noise pollution on wildlife are largely unknown. As more forested lands are converted to industrial use, higher noise levels are being introduced into previously remote areas. The effects of this increase in noise on the sense of hearing, reproductive biology, and behavior of wildlife deserve investigation. Meanwhile, insight to the possible effects can be gained from the results of similar research conducted on farm and laboratory animals.

SOUND PERCEPTION

Preparatory to a discussion of noise impacts, is an understanding of how animals perceive sound. The anatomy of the ear in birds and mammals is similar to man's. Travelling through the air as waves of vibration, sounds enter the external opening of the ear and pass along the auditory canal to a membrane called the eardrum. Responding to the stimulus of the sound wave, the eardrum vibrates at the same frequency as the wave and further transmits it across the bones in the middle ear to a second membrane, the oval window.

Fluid-filled canals of the inner ear then transport the vibrations from the oval window to hair cells in the Organ of Corti. Once stimulated the hair cells activate sensory neurons that carry impulses to the auditory center of the brain. Although this is the mechanism that birds and mammals use to perceive sound, other mechanisms are used by other animals. Many arthropods, for example, have sense organs similar to the eardrum that are capable of vibrating freely in response to the sound wave stimulus.

Animals perceive the three major physical properties of sound vibrations as pitch, volume and tone. The frequency of the vibrations is perceived as pitch. Expressed as the number of cycles per second (Hertz), low-frequency vibrations are perceived as a low pitch, high frequency vibrations are perceived as a high pitch. The amplitude of the vibrations is perceived as volume. Loud sounds cause the fluid in the inner ear to oscillate at a greater amplitude which in turn stimulates more hair cells and sends more impulses to the brain. The volume of a sound (the sound pressure level) is expressed on a logarithmic scale where the unit of measurement is the decibel (dB). This is a relative unit of measurement based on the logarithm of the ratio of sound intensity to a reference level, arbitrarily established as a sound pressure of .002 dynes per cm^2 (a level which was originally judged to be an intensity just audible by man). The final property of sound vibrations, the pattern of harmonics, is perceived as tone. When vibrations are transmitted through the ear hair cells are stimulated both within the Organ of Corti and within other parts of the inner ear. Stimulation of the hair cells outside the Organ of Corti produce secondary vibrations called overtones or harmonics.

Animals differ in their ability to perceive these three properties of sound. The human ear, for example, can detect frequencies from about 16 to 20,000 Hertz (Hz), whereas the avian ear can detect frequencies from about 40 to 29,000 Hz. The moth, on the other hand, has a frequency range that extends up to 100,000 Hz.

Differences in the ability of animals to perceive sound should serve as a caution in extrapolating results of the following studies to animals other than the ones under investigation.

EFFECTS OF NOISE ON LABORATORY AND FARM ANIMALS

The effects of noise have been monitored by structural changes in ear anatomy, physiological changes and behavioral changes. Research on laboratory animals, such as rats, guinea pigs and chinchillas, has dealt primarily with structural and physiological responses to artifical noise systems. Research on farm animals was prompted by numerous complaints from farmers regarding the detrimental effects of sonic booms on their livestock. As a result, this phase of research has dealt primarily with changes in the behavior and "production" of farm animals.

Structural changes

Damage to an animal's auditory system can be the result of exposure to noise of short duration and high intensity (impulse noise) or nosie of long duration and low intensity. It has been repeatedly demonstrated that impulse noise can produce a rapid pressure change capable of rupturing eardrums, disrupting bones of the middle ear or damaging sensory hair cells of the inner ear. For example, Poche, Stockwell, and Ades (1969) exposed 14 young guinea pigs to the noise from five hundred rounds of paper caps. Fired 30 cm from the ear, the noise produced an average sound-pressure level (SPL) of 153 dB. As a result of the exposure, sensory hair cells were destroyed along the Organ of Corti in 11 of the 14 animals. Noise of longer duration and lower intensity can also cause structural damage. Beagley (1965a, 1965b) demonstrated damage to sensory hair cells and supporting structures of the inner ear in guinea pigs exposed for 20 minutes to a SPL of 128 dB.

Damage to the auditory system has also been illustrated by a temporary reduction in an animal's sensitivity to low intensity sounds (Peters, 1965; Benitez, Eldredge and Templer, 1970). Known as a temporary threshold shift (TTS), the reduction in sensitivity can become permanent if the SPL is high and if the duration of exposure is long. Miller, Rothenberg and Eldridge (1972) exposed chinchillas to noise at a SPL of 100 dB (300-600 Hz) for seven days. Five days later, there was evidence of a permanent threshold shift of less than 10 dB at certain frequencies. The extent of structural damage may be considerably reduced by interspersing "quiet" intervals between intervals of noise. Ward and Nelson (1970) exposed two groups of monaural chinchillas to a SPL of 117 dB (700-3000 Hz) for 2 hours. One group was exposed to the noise continuously; one group had eight 15-minute exposures, each separated by a "quiet" interval of 45 minutes. Immediately following the exposure both groups of animals had temporary threshold shifts of more than 100 dB. However, the chinchillas that were exposed to the noise intermittantly completely recovered within 2 weeks, whereas the chinchillas that were exposed to the noise continuously had losses of 40 dB three months after the exposure.

The extent of damage to an animal's auditory system depends on the sound's intensity, duration and pattern of exposure. To date, the majority of studies have dealt with a SPL greater than 100 dB, and often as high as 160 dB. These levels are much higher than most animals normally experience. A sound pressure level of 160 dB, for example, is comparable to the noise directly under a jet airplane at take-off. In addition, all the studies have been relatively short in duration when compared to the animal's life span.

Physiological changes

Adrenal and pituitary effects - By monitoring physiological changes, it has been demonstrated that the response of an animal exposed to intense noise is similar to the response of an animal exposed to other stressful stimuli. Some typical responses have included an increase in heart rate, an increase in blood levels of glucose and ascorbic acid, and an increase in weight of the adrenal gland (EPA, 1971). The physiological mechanism by which an animal responds to intense noise is the same mechanism employed in other stressful situations. The steps were outlined in a 1969 study where rats were exposed to a ringing bell for 2-minutes (Hiroshige, Sato, Ohta and Itoh, 1969). It was shown that the noise stimulus increased the hypothalamus's production of the corticotrophin-releasing factor (CRF). The pituitary gland responded to the CRF by increasing it's production of adrenocorticotrophin hormone (ACTH); the adrenal gland responded to the ACTH by increasing it's production of corticosteriods. This mechanism provides the heart and skeletal muscles with an increased supply of food and oxygen and thereby assists the animal in coping with stress. It is possible, however, to exceed the limits over which this adaptive feedback mechanism can operate (Anthony, Ackerman and Lloyd, 1959). Exposure to a very severe noise stress (e.g. prolonged exposure to an air siren: 160 dB, 20,000 Hz) can result in decreased adrenal activity and pathology in other organs that are influenced by the adrenal secretions, such as the lymphatic organs.

Reproductive effects - Because the reproductive organs are directly influenced by secretions from the adrenal gland, an important concern is the detrimental impact noise pollution may have upon an animal's reproductive biology. At present, the results from numerous studies suggest that the sexual behavior of laboratory and farm animals is not adversely affected by noise. For example, Anthony and Harclerode (1959) demonstrated that the sexual scores of guinea pigs (indicative of six elements of male sexual behavior), exposed to twelve weeks of daily noise (140 dB) for 20 minutes out of every 30 minutes, were not significantly different from the sexual socres of control animals.

Although noise pollution may not be detrimental to an animal's sexual behavior, it may be detrimental to the structure of the reproductive organs and the success of pregnancy. Male mice exposed to the sound of an electric bell 8 hours a day, for 1 to 21 days, developed various testical disorders, including involution of the seminal epithelium and a partial blockage of first order spermatocytes (Zordic, 1959). Female rabbits and rats exposed to a similar auditory stress also developed disorders, including a persistent estrus and enlarged ovaries (Zondek and Isachar, 1964; Singh and Rao, 1970). Such anomalies might be responsible for the decreased fertility that has been observed in some laboratory animals under auditory stress. Perhaps the most serious impacts to an animal's reproductive biology result from exposure to intense noise during gestation. The exposure has been demonstrated as capable of blocking pregnancy (Zondek and Ischar, 1964), producing an increase in birth defects and still-born (Ishii and Yokobori, 1960) and causing a resorption of embryos (Ward, Barletta and Kaye, 1970).

<u>Behavior and Production</u> - The impacts of noise pollution on animals may also be monitored behaviorally. Behavioral responses observed among laboratory animals have included an increase in aggressiveness, a refusal to eat (Monaenkov, 1958), and weakened conditioned reflexes (Borisova, 1960). Many researchers have also noted a reduction in exploratory behavior, an impact that has important implications upon learning ability. Groh (1965), demonstrated that rats raised in a soundproof room learn significantly faster on a straight runaway than rats raised in a noisy animal room.

Initiated by farmers complaints about the negative reactions of livestock to sonic booms, research with farm animals has documented several different behavioral responses. One of the earliest reports (in Bond, 1956) detailed the reactions of dairy cattle to noise that was produced during milking. This study demonstrated that when paper bags were exploded cattle responded with a complete cessation of milk ejection during the 2-minute stimulus. Furthermore, milk production returned to only 70% of normal, thirty minutes after the stimulus ceased. Additional research, primarily with poultry, has also demonstrated how auditory stress may negatively affect production (Stadelman, 1958).

Nevertheless, most farm research suggests that there are no adverse impacts on livestock production from auditory stimuli. Three major studies with beef and dairy cattle established that livestock are capable of adapting to aircraft noise within a few days (Anon., 1973). In several studies, auditory stimuli have even produced a positive effect on livestock production. For example, instrumental music played to lambs (SPL, 100 dB) produced a calming effect and a significant increase in their average daily weight gain (Arehart and Ames, 1972).

WILDLIFE

Demonstrated impacts of noise on wildlife

Few studies have been designed to demonstrate the impacts of noise on wildlife. Currently, the majority of pertinent literature is available in the field of bird control. Research in this field was prompted by the nuisance and potential health hazard caused by extremely large concentrations of blackbirds in many suburban areas. An important means of controlling this problem has been the production of loud noise which initially arouses the birds, causing them to disperse from their area of concentration. Most studies, however, also report that the birds soon adapt to the noise and return within a few days (EPA, 1971).

One of the most widely quoted studies documenting a direct impact to wildlife from noise pollution is a study on Dry Tortugas, Florida in 1969. (Bell, 1970). Sooty terns had been successfully breeding on the island for 50 years, however 99% of the eggs failed to hatch in 1969. It was speculated that the failure resulted from extremely low-altitude supersonic flights over the area that may have driven birds off their nests and damaged the uncovered eggs. Damage to the eggs may have resulted from gull predation, evidenced by a report where pelican eggs were destroyed by gulls when white pelicans were driven off their nests by sonic booms (Grahm, 1969). Condors have also been observed to abandon their nests when disturbed by blasting, sonic booms or traffic (Shaw, 1970). Another significant study on noise pollution and avian reproduction was carried out in Texas by Teer and Truett (1973). A test area was subjected to sonic booms 2-3 times per week during the breeding season. Contrary to the previous evidence, the study was unable to demonstrate that any phase of the reproductive cycle of the wild birds was adversely affected by the disturbance.

The dramatic increase in recreational use of snowmobiles has initiated concern over the impact of vehicle noise on wildlife. Recent research has documented the effects of snowmobile noise on white-tailed deer. The earliest study demonstrated that as snowmobiles moved into an area, the noise (45-75 dB) only resulted in an initial disturbance of deer activity (Bollinger, Rongstad, Soom and Ecstein, 1973). A subsequent study however, demonstrated that impacts of auditory stimuli cannot be determined solely on the basis of behavioral responses. The normal heart rate of a deer is 30-40 beats/minute. When a snowmobile passes by a deer, the heart rate can increase to greater than 300 beats/minute. The same deer will show no behavioral response other than momentary alertness and concern. (Pat Kearns, Minnesota Department of Natural Resources, personnel communication) Another study conducted in St. Croix State Park during the winter of 1972 (Huff and Savage, 1972) demonstrated changes in deer habitat selection that were influenced by high levels of snowmobile activity. During the middle of the week, when snowmobile activity was low, the deer indicated a preference for the large conifer woods. During the weekend however, when snowmobile activity was high, deer movements were restricted to the smaller hardwood areas. Because net radiant heat loss is greater in the hardwood cover type than in the conifer cover type, the authors emphasized the stress that heavy snowmobile use could exert on deer heat maintanence during the winter.

Scattered reports on other organisms have also demonstrated various behavioral and physiological responses to nosie pollution. Indian meal moths exposed to high frequency sounds for 4 days during the larval stage showed a 75% reduction in emerging adults (Kirkpatrick and Harein, 1965). Auditory stimuli may also result in a significant decrease in the reproductive ability of some insects (Cutkomp, 1969). Other studies, however, have not been able to demonstrate any adverse effects (Lindgren, 1969).

CONCLUSION AND SUMMARY

The impacts of noise pollution on wildlife are largely uninvestigated. As industry and recreation continue to infringe upon wilderness areas, the need for more information will become increasingly important. Until more data is available, inferences must be drawn from studies conducted in the laboratory and on the farm.

Although the results are sometimes in contradiction, the majority of research upon laboratory animals demonstrates that intense noise can be detrimental to an animal's hearing, physiology and behavior. Yet, the magnitude of auditory stress that was employed in most laboratory studies (100-160 dB), often exceeded the magnitude of stress commonly encountered even within many industrial facilities (e.g. most mining operations produce a SPL of 100-109 dB at the operator's ear; Bugliarello, Alexandre, Barnes and Wakstein, 1976, p. 221). Furthermore, the stress was generally short in duration compared to the animal's life span; under natural circumstances the stress could extend throughout the animal's entire life. Man is the only organism for which there is sufficent evidence of the detrimental impact noise pollution may have when exposure to noise, even no louder than people shouting, is continued over a period of years for 8 hours a day and 5 days a week. But, as mentioned earlier, the most important reason one should be cautioned about making inferences concerning wildlife from the laboratory studies, is that animals differ in their sensitivity to sounds. Nevertheless, laboratory studies illustrate the potential for detrimental impacts from exposure to noise pollution.

An important point made by the research conducted on farm animals and wildlife is that the animals are capable of adapting to auditory stress. Recent research however, cautions biologists on extrapolating to conclusions concerning physiological adaptation from observations of behavioral adaptation. Even in cases where physiological adaptation is observed, prolonged exposure to auditory, stress may ultimately exceed the limits over which the adaptive physiological feedback mechanism can operate.

It is difficult to predict the type of noise environment that wildlife will be exposed to in the future. The evidence that has been presented however, suggests the need for concern and for further research. Not only is it important to monitor structural, physiological and behavioral changes, it is important to monitor the potential interference noise pollution may have with animal communication. Extraneous noise could mask auditory signals conveying information about distress, danger, alarm, territory, mate recognition, food or young. Interference with the transfer of such information could have a detrimental effect upon spacing patterns, nesting, care of the young and predator and prey detection. Future research must be directed toward these potential problems and employ an experimental design that incorporates an auditory stress of moderate intensity and long duration.

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