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TRANSMISSION LINE AUDIBLE NOISE AND WILDLIFE

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INTRODUCTION

Transmission line rights-of-way have been a conspicuous part of the landscape for many years. Until the advent of extra high voltage lines (EHV, above 230 kV) it was often assumed that transmission lines had a net beneficial effect on wildlife due to the increased habitat diversity produced by cleared rights-of-way (Egler 1953, 1957).

When the first EHV transmission lines were constructed in the U.S. during the 1950's the transmission facilities themselves began to be a more noticeable component of the right-of-way environment and new kinds of environmental impacts were identified. These included greater visual impacts due to the larger physical size of the facilities and electric field and corona effects due to the higher operating voltages. Of the latter effects, audible noise (AN) due to corona (air ionization) was found to be a source of annoyance to persons living near EHV lines (Perry 1972). Concerns have also been raised about the possible effects of transmission line AN on wildlife (Klein 1971, Villmo 1972, Martinka 1974, Driscoll 1975, Fletcher 1975, Balda and Johnson 1976, Grue 1977).

Noise is usually defined as unwanted sound. It can also be described as an environmental pollutant which is a waste product generated by various human activities (EPA 1974). In general, wildlife species are exposed to many of the same environmental noises as man. A recent report included an estimate that as many as 13 million American live in places where noise from cars, buses, trucks, airplanes, construction equipment, and electrical devices may be harming their health (Comptroller General 1977).

Although the hearing ability of wildlife varies greatly among species and may differ significantly from man, a knowledge of the effects of noise on wildlife aids in understanding the effects of noise on man and vice versa. The concept of wildlife as an indicator of environmental quality has been described by a number of authors (Thomas et al. 1973, Jenkins 1972).

Noise can produce in man and animals such effects as hearing loss, masking of communications, behavioral changes, and non-auditory physiological effects (EPA 1974). For wildlife in natural environments, the most observable effects of noise would seem to be changes in animal behavior due in part to the masking of auditory signals. Most wildlife are mobile and could in theory avoid areas of intense noise levels necessary to cause permanent hearing damage.

It is well known that noise can cause great behavioral changes in wildlife. Beginning with the human voice and the clap of hands, and progressing to explosives and more recently to sophisticated sonic generators, man has used noise to repell animals from areas where their presence results in damage to crops or other property (Frings 1964, Busnel and Giban 1968, Stewart 1974).

A report published in 1971 by Memphis State University summarized much of what was then known of the effects of noise on wildlife and other animals (Memphis State Univ. 1971). Of the 103 references cited in the report only one made any reference to the effects of power line noise on wildlife. This single report consisted of a brief mention that the "hum" from power lines (no voltages or sound levels given)adversely affected reindeer (Rangifer tarandus) behavior and contributed to difficulties in herding (Klein 1971).

A report by the U.S. Environmental Protection Agency (EPA 1974) identified a need for information on the effects of noise on wildlife. Included in the report were recommendations for studies to determine the effects on animals of low-level, chronic noise, and for comprehensive studies on the effects of noise on animals in their natural habitats. The subject of this paper is the possible effects of relatively low-level transmission line AN on wildlife in natural environments.

This paper has the following objectives:

1) To describe the characteristics of transmission line AN and its effects on the human environment.
2) To relate these effects to the possible effects of AN on wildlife,
3) To relate the effects of AN to the overall effect of a transmission line and associated right-of-way, and
4) To describe research efforts of the Bonneville Power Administration (BPA) which are beginning to provide information for evaluating the effects of AN and other transmission line parameters on wildlife.

The effect of transmission line AN on wildlife is most reasonably considered when in the context of the overall effect that transmission lines have on wildlife. Noise from corona discharges is only one component of the complex environment that exists in the vicinity of a transmission line right-of-way. In addition to AN, wildlife on a right-of-way may be simultaneously exposed to human activity on access roads, shiny metal towers and conductors, electric and magnetic fields, and chemically-treated vegetation. It is a complex undertaking to determine the singular or combined impact of these components on various wildlife species which have widely differing biological and ecological characteristics which vary with season, weather, and habitat conditions.

TRANSMISSION LINE CHARACTERISTICS

An understanding of general transmission line characteristics is necessary to place the effects of AN in proper perspective. Although this discussion of transmission line construction, maintenance, and operation characterisitics relates primarily to the BPA transmission system, much of it will apply to transmission lines in general.

Transmission lines carry electrical power from generation sources to load centers. There the power is transformed to lower voltages in substations for distribution over smaller lines to users.

As an indication of the extent that transmission lines have become a part of our environment, consider that in 1970 there were an estimated 480,000 km of transmission lines in the United States (USDI and USDA 1970). The BPA system alone in the Pacific Northwest consists of over 20,000 km of transmission lines (Figure 1). Of these over 5,600 km are 345 kV and above. It has been estimated that for the balance of this century approximately 160,000 km of new transmission lines will be constructed on 60,700 ha of right-of-way each decade (USDI and USDA 1970). It is unlikely that underground transmission will be used to any great extent in the next few decades due to the high costs involved (Truax 1975).

Transmission structures vary greatly in shape and size depending on such factors as line voltage, topography, esthetics, and technical and safety design considerations (BPA 1975). EHV transmission lines usually require metal towers to support the weight of conducting wires (Figure 2). In some cases one structure supports two electrical circuits. This results in a significant decrease in right-of-way width required compared to that needed for two single circuit lines but requires the use of taller towers.

The trend has been to build transmission lines with higher operating voltages because the power carrying capacity is significantly increased with increases in voltages. For example, a 1200-kV transmission line could carry approximately six times the power carried by a single circuit 500-kV line but would require a right-of-way only 15.4 m wider (BPA 1976a). Presently, 765-kV is the highest a-c voltage for operational transmission lines in the U.S. BPA has constructed a 1100/1200-kV prototype transmission line and lines of this voltage are expected to be in use in the 1980's.

Construction

Transmission line construction usually involves vegetation clearing, access road construction, tower footing installation, tower assembly and erection, conductor stringing and site restoration (BPA 1974). The environmental impact of this construction varies widely depending on such factors as size and length of line, topography and vegetation types encountered, weather, and time of year during which construction occurs (Goodland 1973). In general, lines constructed in steep forested areas where many new access roads are required result in the greatest impact during the construction phase. At the other extreme, lines constructed through level grassland may result in comparatively few

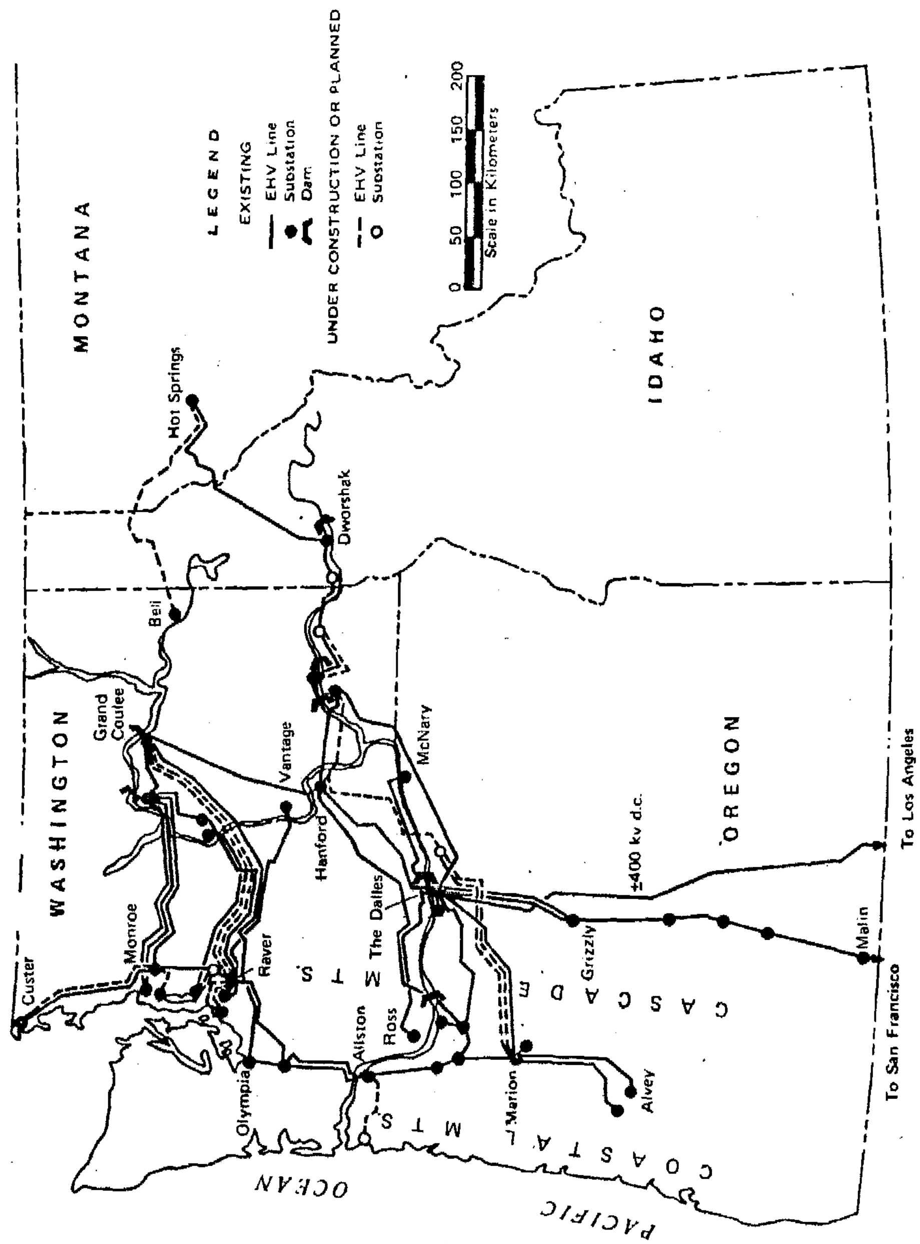


Figure 1 - Bonneville Power Administration Service area showing E.H.V. transmission lines (345 kV,500 kV,±kv d.c.).

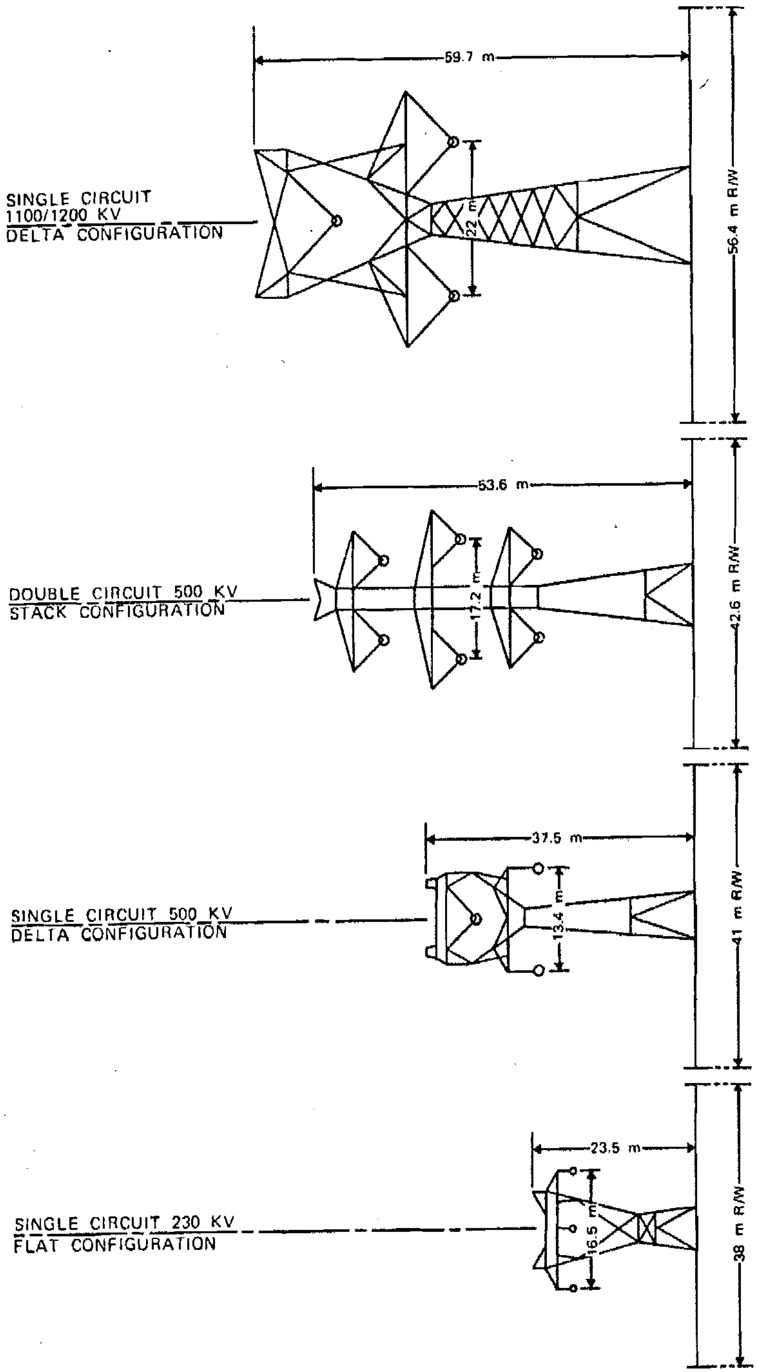


Figure 2 - Configurations of typical B.P.A. transmission structure. Scale is approximate.

environmental impacts during construction.

On older transmission lines a cleared right-of-way through forest habitat is one of the most characteristic features of a transmission line right-of-way. On some newer lines more selective clearing is practiced resulting in a "feathered" appearance.

Access roads can also be a primary feature of a transmission line right-of-way especially in forested areas. Roads are required for both constructing and maintaining transmission lines. Although existing roads are used where possible new roads are often required both on and off the right-of-way. Where access roads are constructed across public lands such roads can receive heavy use by recreationists including hunters, campers, fishermen, and off-road vehicle enthusiasts. Increased human access to previously remote areas can have significant consequences for wildlife, especially those species that require wilderness type habitat.

The final stage of construction consists of removing all equipment, and material, and debris and restoring disturbed sites. Unmerchantable trees and brush removed from the right-of-way and access roads are usually burned on the construction site. Tower sites and other disturbed areas are recontoured. Disturbed areas are often seeded to facilitate the regrowth of vegetation.

As indicated above, construction of a transmission line can result in significant environmental disturbances. The resulting impact of construction on wildlife can be reduced in some cases by the use of mitigation measures (BPA 1974, USDI and USDA 1970).

Quantitative information on the above types of impacts of construction activities on wildlife is rare. BPA line construction personnel have reported that deer (Odocoileus spp.) and elk (Cervus canadensis) are frequently observed near construction sites. Other more secretive species may avoid construction areas although during construction of the BPA prototype 1100/1200-kV line a cougar (Felis concolor) observed near the right-of-way did not appear to be greatly disturbed by the activity of men and equipment. Construction activity at the site did not appear to have any large effect on on the abundance of birds and small animals. Stahlecker (1975) reported that wildlife activity ceased when workers were constructing a 230 kV transmission line in Colorado. He also found that survey stakes, tower material and other equipment were used as singing perches by some birds. He reported that construction activity may have caused some birds to desert their nests. Other than possible adverse effects on Ord's kangaroo rat (Dipodomys ordi) due to destruction of burrows, he found no evidence that other small mammals were adversely affected by construction. Balda and Johnson (1976:7-18) reported that construction of two 500-kV transmission lines in Arizona resulted in drastic differences in the species diversity of small mammals but that the differences were transient in nature.

Maintenance

There occurs during the operating life of a transmission line a variety of activities to maintain the facilities and insure high system reliability. Of primary interest as far as wildlife are concerned are vegetation management activities. Brush and trees on rights-of-way are controlled so that they will not grow into conductors or impede restoration of service if outages occur (BPA 1974). Vegetation management is accomplished in a variety of ways including both mechanical cutting and chemical treatments. The result, in forested areas, is that plant succesion is maintained in a shrub/grass stage.

Cleared rights-of-way are probably utilized by most of the same wildlife species that inhabit the adjacent forest (Cavanagh et al. 1976). In some cases the right-of-way may attract species and communities which differ from those found in the original forest (Schreiber et al. 1976). The "edge effect" has been used to describe the phenomenon where wildlife utilize areas of overlapping habitat types to a greater degree than they utilize the adjoining habitats (Odum 1959). Several studies have documented the effects that clearings, whether man made or natural can have on wildlife (Lay 1938, Edgerton 1972, Walmo et al. 1972, Pengelly 1973, Patton 1974).

For transmission lines the width of the cleared right-of-way can be an important consideration. Anderson et al. (1977) found that in deciduous forests a 12 m wide right-of-way had reduced bird species diversity compared to the adjacent forest. A 30.5 m wide right-of-way had high bird species density and diversity and a 91.5 m wide right-of-way had less diversity but attracted species not found in the adjacent forest.

Although herbicides are recognized as potentially

hazardous to wildlife, with proper application techniques they can be used effectively to control right-of-way vegetation while only minimally affecting non-target organisms (Buffington 1974). Since 1970 BPA has sponsored research to evaluate herbicides used on transmission line rights-of-way (Norris 1971). This research also shows that these chemicals can be used without noticeable adverse effects to animals. Buffington's (1974) review pointed out some possible effects of herbicides on wildlife which have not received a great deal of attention. These include the possible adverse effects of herbicides on rumen flora of large herbivores.

Mayer (1976) studied wildlife usage of power line (no voltages given) rights-of-way in the eastern U.S. which had been maintained by the use of herbicides. Wildlife species included whitetail deer (Odocoileus virginanus) ruffed grouse (Bonasa umbellus) gray squirrel (Sciurus carolinensis) bobwhite quail (Colinus virginianus), and cottontail rabbit (Sylvilagus floridanus). Results of the study showed that wildlife utilized the rights-of-way to a greater degree than they utilized habitats adjacent to the right-of-way.

Vegetation on rights-of-way can also be controlled by selective cutting and this can also have an effect on wildlife usage. Cavanagh et al. (1976) found that wildlife usage of selectively maintained powerline (no voltage given) rights-of-way was higher than usage of clearcut rights-of-way. Costs for selectively maintaining the rights-of-way was approximately 12 times that required for maintaining the clearcut rights-of-way.

Operation

The electrical properties of an operating transmission line result in field effects and corona effects. A consideration of the electrical effects of transmission lines is necessary in both the design of biological studies and in the interpretation of results. The following is an introduction to the electrical characteristics of EHV transmission lines. Persons unfamiliar with transmission lines contemplating biological research in this area should seek advice and assistance from persons with training in such fields as electrical engineering and physics.

Field Effects

Voltage applied to a transmission line conductor produces an electric field in the region surrounding the conductor and extending to the earth. Current flowing in a conductor produces a magnetic field. At a common measurement height of 1 m above ground, the maximum electric field strength (voltage gradient) beneath BPA 500-kV lines with a conductor to ground clearance of 11 m is about 8-kV/m (BSTT 1977). The electric field strength near an a-c transmission line can be measured with a hand-held meter available from various manufacturers. Field strength can also be computed (Deno and Zaffanella 1975). The maximum magnetic field strength of such lines is approximately .6 Gauss (BSTT 1977). The electric field strength beneath 765-kV lines, with a conductor to ground clearance of 17 m is 9-10 kV/m (SNYPC 1976). These maximum field strength levels occur in a relatively small area at mid span beneath the conductors. At the edge of a 500-kV transmission line right-of-way maximum field strength is from 2.5 - 3.5 kV/m (BSTT 1977). Maximum field strength beneath BPA 230 kV lines is 3-4 kV/m. For reference, the electric field strength 30 cm from an electric blanket is approximately 0.25 kV/m and 60 Hz electric fields inside a typical house may range from less than 0.001 kV/m up to 0.013 kV/m (Miller 1974).

When conducting objects such as vehicles, persons, or animals are in an electric field, currents and voltages are induced in them (BSTT 1977). Usually these currents and voltages are below the perception level for humans. Under certain circumstances annoying spark discharge shocks can occur to people and animals in the vicinity of transmission lines. These circumstances occur when a person or animal, insulated from ground, comes in contact with a grounded object, or when the object is insulated and the person or animal is grounded. Such shocks are similar to what one experiences after walking across a carpet and touching a door knob. Conducting objects near transmission lines such as metal fences are routinely grounded to prevent the build-up of large voltages on such objects (BSTT 1977). The magnetic field can also induce voltage and currents although the effects are not as apparent as for the electric field.

The presence of electric fields can also be sensed if the magnitudes are great enough. Deno and Zaffanella (1975) reported the threshold for perception of an electric field (e.g., hair stimulation) for the most sensitive 10 percent of the persons tested was between 10 and 15-kV/m. We have felt hair stimulation on our extended arms beneath a BPA 500-kV line with an estimated field strength of 7-8 kV/m. When standing on dry ground with rubber soled shoes, we could also perceive a slight tingling sensation when touching

vegetation.

Relatively little is known about the perception of animals to electric fields. In one study there were no visible changes in grazing, feeding, and drinking habits of cattle on damp ground in electric fields of 18-kV/m (Deno and Zaffanella 1975). Those authors, however, suggested that on dry ground, spark discharges might occur between grounded objects and the bodies of animals. Researchers at Battelle Pacific Northwest Laboratories saw no hair movement on the ear of an anesthetized swine until field strength reached 50-55 kV/m (Phillips et al. 1976).

Radar tracking studies conducted by Larkwin and Sutherland (1977) suggested that during nocturnal migratory flight, birds were apparently able to sense low intensity a-c (72-80) electromagnetic fields produced by a large antenna system. The two antennas used in the study were each 22.6 km long and 8 m above ground. They produced an electric field of 0.07 V/m at 100-400 m and the magnetic field at these distances was less than 1 percent of the earth's magnetic field.

Lott and McCain (1973) used implanted electrodes to determine if rats were aware of an external electric field. When in a d-c positive field of at least 10 kV/m rats showed a statistically significant increase in brain activity (EEG) which was reported as an indication the rats were aware of the field.

In recent years considerable interest has arisen over the question of whether low intensity electric and magnetic fields can result in biologic effects as a result of long term exposure (Young and Young 1974, Llaurado et al. 1974). At the present time the bulk of the available evidence does not indicate that transmission lines pose a significant biological hazard in this regard (Bridges 1975, BSTT 1977, Janes 1976). Additional information is needed, however, for assessing the potential for such effects.

In addition, studies done on the biologic effects of ions at concentration levels similar to those produced by a d-c transmission line suggest both beneficial and adverse effects are possible (Krueger and Reed 1976). Several studies are underway in the U.S. which should provide more definitive information on the nature and significance of biologic effects from electric and magnetic fields. A review of the above topics and listing of this research can be found in a BPA publication (BSTT 1977).

A d-c transmission line has similar electrical parameters as an a-c line, however, there are some differences. Corona-generated ions from a d-c transmission line form a "space charge" which alters the electric field near the line (Hill et al. 1977). Ions are greatly affected by wind and consequently the ground level electric field for a d-c line frequently changes in location and magnitude. On the Celilo-Sylmar ± 400-kV d-c line electric field strengths of -34 kV/m have been measured with approximately half of this due to enhancement by the space charge (Bracken et al. 1977).

For reference, the earth's d-c electric field averages 0.13 kV/m and beneath thunderclouds levels of 3 kV/m or higher may exist even in the absence of lightning (Polk 1974). The magnetic field of a d-c line is approximately the same level as the .6 G d-c field of the earth.

It should be pointed out that d-c electric field strength values cannot be directly compared with a.c. values. Even with d-c electric fields of 40 kV/m the current intercepted by persons beneath a d-c tramsmission line is many times below the perception level (Hill et al. 1977). The probability of receiving perceivable spark discharge shocks in the proximity of a d-c line is also less than for comparable a-c lines (Hill et al. 1977).

Audible Noise (AN)

When the electric field intensity on the surface of a transmission line conductor exceeds the breakdown strength of air, corona dischrages occur (Deno and Comber 1975). Corona results in AN, radio and television interference, flashes of light, and production of oxidants (primarily ozone). Of these, AN is probably the more important as far as possible effects on wildlife are concerned. Studies have shown that the amount of ozone produced by transmission lines is generally not measurable above ambient levels (Sebo et al. 1976, Roach et al. 1977).

The subject of transmission line AN has been discussed in a number of papers (Perry 1972, Ianna et al. 1973, Comber and Zaffanella 1975). What follows is a summary of pertinent aspects of corona produced noise which provides a basis for determining the possible effects of such noise on wildlife.

Depending on such factors as line voltage, conductor design and surface irregularities, and weather, transmission

line AN can vary widely. It is most noticeable on a-c lines of 500 kV or higher. For such lines the noise is characterized by a random broadband, crackling, hissing sound with a 120 Hz "hum" or harmonics of this frequency occasionally present. The characteristics of AN from d-c transmission lines is described later in this section. Although usually termed "audible noise", corona noise actually extends to frequencies above the limits of the human hearing range (Ianna et al. 1973).

Corona discharges result in power losses and therefore a-c transmission lines are designed to operate in fair weather below the corona onset level. A common design is the use of a number of subconductors to transmit the power in each of the three phases of an a-c transmission line or the two poles in the case of a d-c line. This has the effect of increasing the overall surface area of the conducting material. This reduces the voltage gradient on the conductor surface and thus reduces the occurrence of corona.

In reality corona can occur with EHV lines even during fair weather because of imperfections or contaminants on the conductors. Although nicks, scrapes, insects, and dust can cause corona, water on the conductors is the most important cause. A-c transmission line AN is generally highest during heavy rain. Ambient noise, however, is also high during heavy rain so AN is more apparent during snow, fog, light rain, mist, or just after a rain while the conductors are still wet.

The age of the conductors also has an effect on the amount of AN produced. The surface of a new conductor has a light coating of grease which causes water droplets to form over the entire conductor surface (Perry 1972). As the conductor ages, corona and weather combine to change the conductor surface conditions so that water droplets tend to form only on the underside of the conductor. This reduces the effective number of corona discharge points and lowers AN compared to the new conductor. AN may reach its highest levels during the first few years after a line is constructed which is also the time when the "newness" of the overall facility may have its greatest effect on wildlife.

Other factors which can affect AN production include the configuration of the subconductor bundles, phase spacing and phase configuration, height of the conductors above the ground, and proximity of other circuits which may be on the same transmission structure or on adjacent ones.

Analysis of transmission line AN should include both the broadband and the pure tone components. The 120 Hz hum (and other multiples of this tone) is produced by the rapid oscillation of ionized air ions near the conductor surface which have been generated by corona. Although the 120 Hz hum correlates with corona, the relative magnitude of the random noise and the 120 Hz hum can differ depending on weather conditions. The 120 Hz hum does not attenuate as rapidly as the high frequency random noise and it therefore may be detected at greater distances from the transmission line. At certain times in central Oregon with ambient noise levels of approximately 20 dB(A) we have heard the hum from two 500-kV a-c transmission lines from almost 2 km away.

A standard procedure for making measurements of transmission line AN has been developed (IEEE Committee Report 1972). Measurements of AN are often reported in dB(A). The "A" weighting network discriminates against lower frequencies including 120 Hz, so dB(A) measurements of AN actually pertain primarily to the random noise (Comber and Zaffanella 1975).

Figure 3 shows a lateral profile of AN measurements for a 500-kV line during rain.

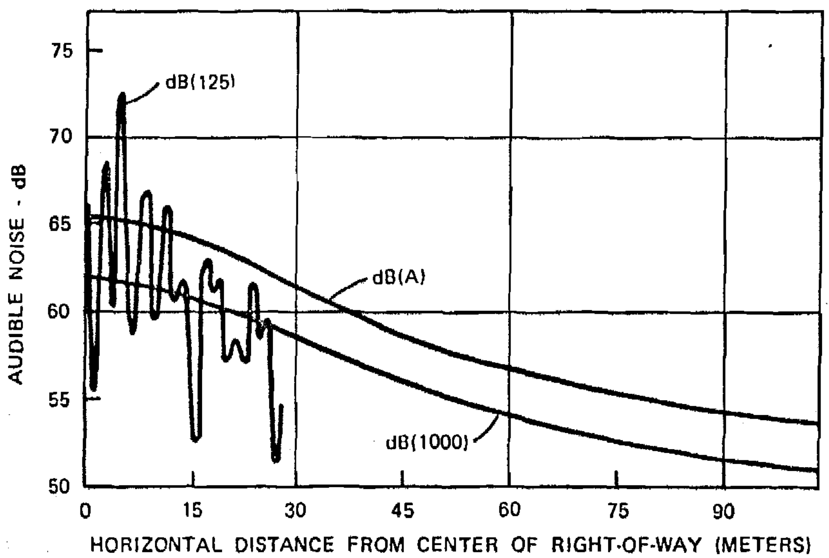


Figure 3 - Typical lateral profile of audible noise from a 500 kV a-c transmission line with one 6.35 cm conductor for each phase. Adapted from Perry (1972).

Note that AN levels measured at various distances from a transmission line are functions of distance and the combination of random noise and hum generated from each phase of the line. The strength of the 120 Hz hum can vary several dB as a consequence of displacing the measuring microphone a few meters.

In determining the environmental effect of transmission line AN it is important to consider it in relation to ambient noise levels. If the AN measured for a transmission line is at least 10 dB above ambient, the measured AN is essentially from the line (Comber and Zaffanella 1975:197). Those authors further indicate that when differences measured between ambient and the transmission line are 3 dB or less the two conditions cannot be separated by conventional measures. It should be pointed out that the above refers to measurable levels. The AN may still be audible even when the level is similar to ambient due to its unique frequency characteristics.

As described above, AN varies greatly in intensity and frequency composition depending on a number of factors foremost of which is weather. In considering the possible effects of AN on wildlife, it is important to keep in mind that animals that may inhabit areas near an a-c transmission line right-of-way are not exposed to a constant level of noise. Figures 4 and 5 are examples of the kinds of variations in AN which can be expected from EHV transmission lines.

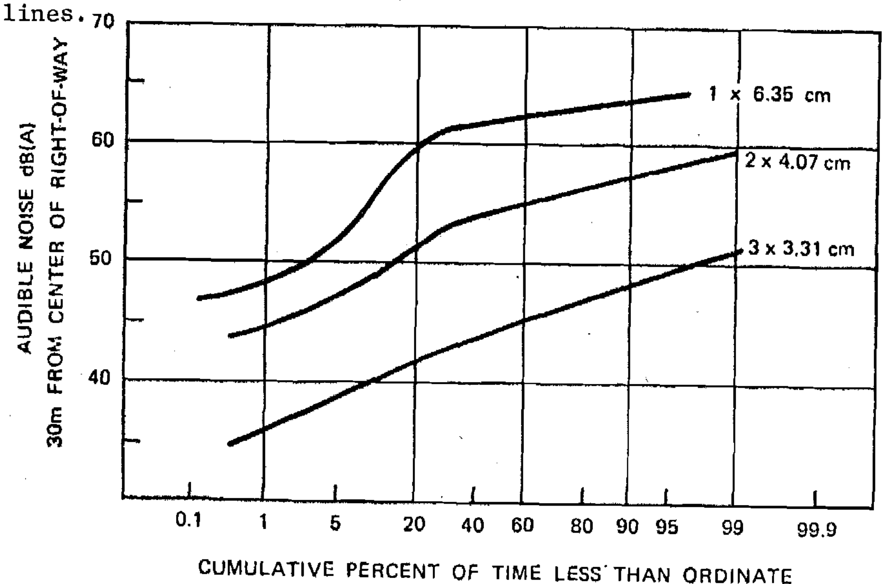


Figure 4 - Cumulative frequency distribution for audible noise from a 500 kV a-c transmission line with one 6.35 cm conductor [illegible]

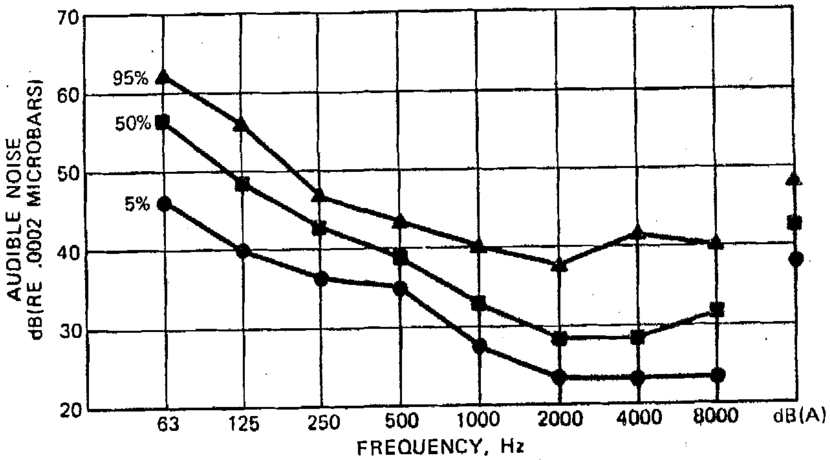


Figure 5a - Audible noise spectrum during fair weather or a 775 kV a-c test transmission line with four 35.1 mm diameter conductors per phase. Noise level is less than the ordinate the indicated percentage of time. Redrawn from Kolcio et al. (1973).

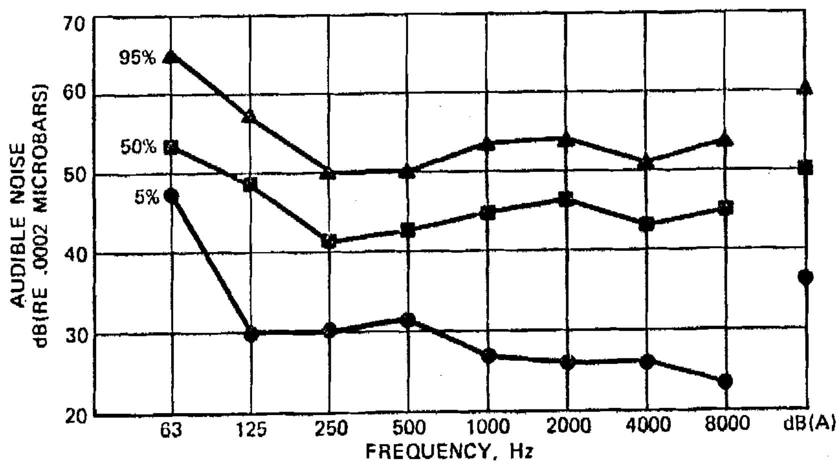


Figure 5b - Audible noise spectrum during fog for a 775 kV a-c test transmission line with four 35.1 mm diameter conductors per phase. Noise level is less than the ordinate for the indicated percentage of time. Redrawn from Kolcio et al. (1973).

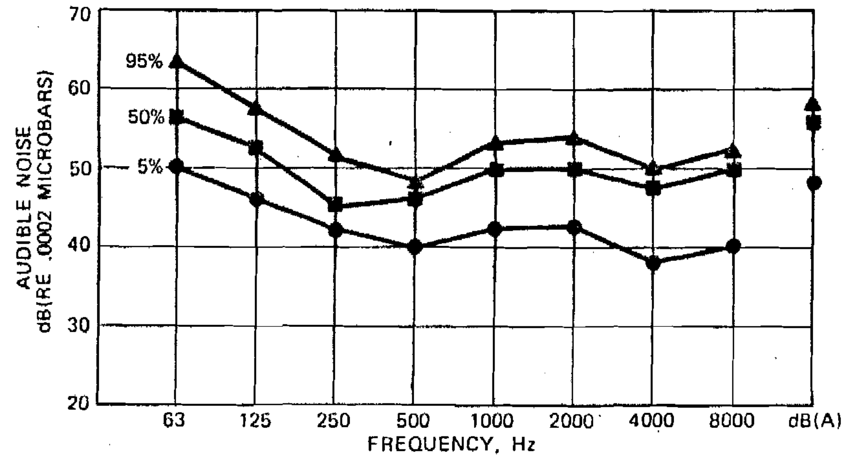


Figure 5c - Audible noise spectrum during rain for a 775 kV a-c test transmission line with four 35.1 mm diameter conductors per phase. Noise level is less than the ordinate for the indicated percentage of time. Redrawn from Kolcio et al. (1973).

Although there is no difference in the mechanism of a-c and d-c corona, there are sufficient differences in AN associated with the two types of transmission lines to warrant a brief discussion. This discussion is based primarily on information contained in a recently published reference book on HVDC transmission (Hill et al. 1977).

Unlike three phase a-c lines, a d-c transmission line has only two sets of conductors (poles), one negative and one positive. The positive pole is the primary source of AN. The noise is characterized by impulsive pops and is similar to the random noise of the a-c line without the 120 Hz hum. The frequency characteristics of the d-c AN are generally similar to the a-c random AN.

A major differnce between the two types of lines is that d-c corona loss is less affected by weather than is a-c. Correspondingly, as compared to a-c lines, AN from a d-c line changes less between fair and inclement weather conditions. Studies with a d-c test line at the Dalles, Oregon showed that rain may even cause a very slight decrease in d-c AN levels and snow had no significant effect (Hill et al. 1977: 67). Maximum AN levels measured for the d-c test line ranged from 30 dB(A) with the line operating at $\pm$ 400 kV, to 48 dB(A) at $\pm$ 600 kV. Note that for a d-c line, voltage is usually reported as the difference in potential between the positive and negative poles and ground. Sometimes the operating voltage is reported as the total potential between the two poles. In this latter case ± 400 kV d-c would be reported as 800 kV d-c.

To gain a better understanding of how AN from transmission lines could affect wildlife one can first consider its effects on people. For reference, Table 1 shows levels of familiar noises and gives human responses to such noises. AN can be a source of annoyance to persons living near EHV transmission lines.

The concept of "annoyance" in regards to wildlife is not well defined. Stewart (1974) whose company manufactures sonic animal repellent devices believed that humans and lower animals have much in common regarding their responses to noise. Consequently the widely use "Av-Alarm" sonic generator successfully used in bird and mammal control work was designed to produce the kinds of noise that promote annoyance, nervousness, and discomfort in people (Stewart 1974).

One measure of the degree of human annoyance to transmission line AN is the number of complaints a power company receives. A guideline to the probability of receiving complaints about AN was developed by Perry (1972). When AN levels 30 m from the center of the right-of-way are approximately 53 dB(A) or lower no complainst would be expected. AN above 59 dB(A) can result in numerous complaints. Perry (1972) cautioned that in practice the "acceptability" of AN of various levels varies depending on such factors as ambient noise, population density and level of 120 Hz or other tones present in the AN.

Because of problems with audible noise BPA no longer builds new 500-kV lines with a single subconductor per phase and some lines of this type have been reconductored to the newer three subconductor per phase design.

The subject of AN was one of the central issues in extensive hearings held by the State of New York Public Service Commission for the purpose of certifying the construction of 765-kV transmission lines in that state. The hearings began in 1974 and by June 1976 the testimony of over 26 scientists and engineers had filled more than 10,000 pages (SYNPSC 1976). In addition to AN, testimony was taken on ozone, induced electric shocks, and on the biological effects of electric fields.

Table 1. Examples of Environmental Noise Levels and Typical Human Responses. (Source: EPA 1972)

	Noise Level (Decibels)	Human Responses	Conversational Relationships
	150		
Carrier Deck Jet Operation	140		
		Painfully Loud	
	130	Limit Amplified Speech	
Jet Takeoff at 61 m	120		
Discotheque		Maximum Vocal Effort	
Auto Horn at .9 m			
Riveting Machine	110		
Jet Takeoff at 610 m			Shouting in ear
Garbage Truck	100		
N.Y. Subway Station		Very Annoying	
Heavy Truck at 15 m	90	Hearing Damage (8 hours)	Shouting at .6 m
Pneumatic Drill at 15 m Alarm Clock	80	Annoying	Very Loud Conversation at .6 m
Freight Train at 15 m			
Freeway Traffic at 15 m	70 1/	Telephone Use Difficult	Loud Conversation at .6 m
Air Conditioning Unit at 6 m	60	Intrusive	Loud Conversation at 1.2 m
Light Auto Traffic at 30 m	50	Quiet	Normal Conversation at 3.7 m
Library	40		
Soft Whisper at 4.6 m	30	Very Quiet	
Broadcasting Studio	20		
	10	Just Audible	
	0	Threshold of Hearing	

1/ Contribution to hearing impairment begins.

The proposed 765-kV transmission lines considered in the hearings would produce a maximum AN level less than 60 dB(A) at the edge of a 76 m wide right-of-way. Sleep interference was the most serious possible effect predicted for AN. Although the testimony in the hearings dealt primarily with humans, at least two witnesses addressed possible effects on wildlife (Driscoll 1976, Fletcher 1976). Fletcher (1976) suggested that AN from the proposed 765-kV lines could at times mask certain acoustic signals that could be critical to the survival of some animals. He added that such effects on wildlife, however, would probably be insignificant. Further, scientific evidence on which to base those predictions were almost completely lacking according to Fletcher. Driscoll (1975) believed AN could affect wildlife breeding activities and predator-prey relationships. He suggested the right-of-way may be less desirable to wildlife during inclement weather because of high levels of AN. He also felt that little information was available to permit quantitative assessment of the effects of AN on wildlife and that research on the subject was needed.

One of the major difficulties in determining human annoyance levels associated with AN is that annoyance is determined by a number of psychological factors. Anticaglia (1970:2) pointed out that evaluation of noise by people involves both the consideration of the physical sound and the subjective impression in the listener's mind. For example any amount of AN may be extremely annoying to a person when it is coming from a transmission line which was constructed across his property against his wishes and only after a lengthy condemnation proceeding.

Most of the literature dealing with the biologic effects of transmission line AN is oriented toward possible effects on humans. In relating this literature to wildlife some distinctions should be made. One of the main distinctions is that AN as usually reported for transmission lines is for locations at the edge of the right-of-way or beyond. Easements purchased for rights-of-way are for the purposes of operating and maintaining the transmission line so persons who might find the higher AN levels on the right-of-way objectionable are not obliged to stay there. Wildlife of course are not aware of the existence of legal right-of-way boundaries. In considering the possible effects of AN on wildlife it is therefore necessary to know the maximum AN levels which occur on the right-of-way as well as levels at various lateral distances. As previously mentioned AN levels can change significantly within short distance from the line.

A related factor is that people are usually inside closed buildings during inclement weather when a-c transmission line AN is highest. Wildlife, however, may still be moving about and have greater opportunity to encounter the high levels of AN. Unfortunately, relatively little has been reported in the literature about the effects of weather on various wildlife species at different seasons of the year. Species that become dormant during winter or that migrate may encounter high levels of AN less frequently than resident species. Rain, wind, and snow also adversely affect an observer's ability to detect and study animals (Overton and Davis 1969:425).

Another distinction is that AN measured in dB(A) may not be the most appropriate measure of the noise as it is perceived by wildlife. Although some species, including most birds, have a hearing range which approximates that of man other species may be sensitive to a much wider range of frequencies. For a-c lines at least it is important to consider the tonal component of the noise including frequencies outside of those normally considered of importance to man.

Table 2 shows frequency hearing ranges of various animals as compared with man. Many insects respond to frequencies far above those audible to humans. The hearing of most birds is similar to man and although many bird vocalizations contain ultrasonic frequencies birds probably cannot hear such frequencies (Sales and Pye 1974). Mammals respond to a wide range of frequencies including those audible to man and those in the ultrasonic range. In reptiles the importance of sound perception is subordinate to vision and chemoreception and sound producing mechanisms are absent in most reptiles (Bogert 1960).

As mentioned previously corona can produce ultrasonic frequencies. We are not aware of any study in which ultrasonic frequencies were measured in the corona noise produced by a transmission line under normal operating conditions. Ianna et al. (1973) studied the spectral characteristics of corona produced by metallic protrusion on conductors in a laboratory. In one test with a voltage gradient on the conductor of 13.3 kV/cm negative dc, the peak of the acoustic spectra was between 24-26 kHz.

Although it is reasonable to assume that transmission line corona could produce ultrasonic frequencies which could be heard by certain wildlife species, it is less likely that such frequencies have any significant effect except very near the conductors. Ultrasonic frequencies are rapidly at-

Table 2. Hearing Abilities (Frequencies) of Various Animals as Compared With Man.

Species	Lower Limit (Hz)	Maximum Sensitivity (Hz)	Upper Limit (Hz)	Source
Man (Homo sapiens)	16	4,000	20,000	EPA (1974)
		Invertebrates		
Tiger moths 1/ (Arctiidae)	3,000	--	20,000	Haskell and Belton (1956)
Noctuid moth 1/ (Prodenia evidania)	3,000	15,000-60,000	240,000	Roeder and Treat (1957)
Butterflies (38 species) 1/ (Lepidoptera)	--	40,000-80,000	--	Schaller and Timm (1949,1950) cited in Autrum (1963)
Long-horned grasshoppers 1/ (Tettigoniidae)	800-1,000	10,000-60,000	90,000	Wever and Vernon (1957)
Field cricket 1/ (Gryllus)	300	--	8,000	Wever and Bray (1933)
Mosquitoe 2/ (Anopheles subpictus)	150	380	550	Tischner (1953), cited in Autrum (1963)
Male Midges 2/ (Tendipedidae)		80-800 with peaks at 125 and 250		Frings and Frings (1959)
		Amphibians		
Bullfrog (Rana catesbeiana)	<10	<1,800	3,000-4,000	Strother (1959)
		Birds		
Starling (Sturnus vulgaris)	<100	2,000	15,000	Granit (1941), cited in Bremond (1963)
House sparrow (Passer domesticus)	--	--	18,000	Granit (1941), cited in Bremond (1963)
Crow (Corvus brachyrhynchos)	<300	1,000-2,000	>8,000	Trainer (1946)
Kestrel (Sparrow Hawk) (Falco sparverius)	300	2,000	>10,000	Trainer (1946)

Table 2. Hearing Abilities (Frequencies) of Various Animals as Compared With Man. (cont.)

Species	Lower Limit (Hz)	Maximum Sensitivity (Hz)	Upper Limit (Hz)	Source
Long eared owl (Asio otus)	<100	6,000	18,000	Schwartzkopff (1955)
Mallard duck (Anas platyrhynchos)	300	2,000-3,000	>8,000	Trainer (1946)
		Mammals		
Bats (Chiroptera)	<1,000	30,000-100,000	150,000	Sales and Pye (1974)
Rodents (Rodentia)	<1,000	5,000-18,000, and 40,000-60,000	100,000	Sales and Pye (1974)
Cats (Felidae)	--	--	70,000	Evans (1968) cited in Sales and Pye (1974)
Opossum (Didelphus virginiana)	<500	--	>60,000	Sales and Pye (1974)

1/ Frequencies of continuous tones that stimulate the tympanal organs.
2/ Frequency response of Johnston's Organ which are located at the base of the antennae.

tenuated especially by fog (Sales and Pye 1974). Those authors also suggested that bats seem to avoid flying during fog because these animals utilize ultrasonic echo location for navigation. Atmospheric moisture, while causing production of corona and possibly ultrasonic frequencies, also acts to decrease the propagation of these sounds.

Another point pertains to the ambient noise levels with which transmission line AN levels are compared. Even when considering the possible effects of AN on people the significance of extremely low ambient levels as a basis for comparison of the AN is sometimes overlooked. The range of environmental sound levels in the U.S. is very great. The range of day-night (L_{dn}) sound levels extend from the region of 20-30 dB for wilderness areas to the region of 80-90 dB or higher in noisy urban areas (EPA 1974). It should be pointed out that even sounds in the natural environment can reach high levels. Griffin (1976) measured sound levels near a frog pond on a still night and found that steady frog calling produced noise levels of 55-60 dB(A) with peaks to 75 dB(A). Waterfalls may produce noise levels of 85 dB(A) or more (EPA 1974).

In contrast, on a number of occasions we have measured sound levels as low as 15-20 dB(A) in central Oregon in places far from human development. At such low levels one strains to hear the slightest sound. Even light to moderate levels of transmission line AN contrasted to these conditions can be annoying.

Frings (1964) reported that in pest control applications the use of amplified communication signals as low as 3 dB above ambient can cause reactions in birds. When male Japanese quail (Coturnix japonica) were exposed for two hours to white noise at levels of 12 dB(A) above ambient the birds significantly increased the frequency of their separation crowing (Potash 1972). Such a response to increases in ambient noise may aid a separated pair of quail in re-establishing contact. As Potash (1972) pointed out, however, the increased chance of being detected by the prospective receiver must be weighed against the chance of being detected by a predator. In another case, Frings and Frings (1959) found that small male flies (Pentaneura aspera) responded with an agitated circling and gathered around the sound source when it was producing 125 Hz tones 13-18 dB above ambient or 250 Hz at 3-8 dB above ambient.

The fact that noise from electrical devices can attract insects has been noted by others (Sotavalta 1963:387). This raises the possibility that although transmission line AN may repel some species, it may attract others. Also, insects attracted to the right-of-way could also influence the density and distribution of insectivorous birds in the vicinity of transmission lines.

Another point regarding distinctions between human and animal responses to transmission line AN pertains to the meaning of noise. As previously mentioned, noise is usually defined as something unwanted. From the human viewpoint it is difficult to imagine any positive effects of transmission line AN. For wildlife, sounds from the inanimate environment are potential carriers of useful information (Emlen 1960:xi). For some kinds of wildlife the possibility exists that the sound produced by a transmission line could act as a navigational aid. Although this suggestion is highly speculative at this time we feel it is worthy of consideration in light of recent research. In one report, Griffin (1975) presented evidence which suggested that on cloudy or foggy nights migrating birds may obtain navigational information from sounds characteristic of particular environments. Yodlowski et al. (1977) reported that homing pigeons can detect sound energy below 10 Hz at amplitudes within the range of those occuring in the environment. "Properly utilized, infrasound information could thus assist in almost every aspect of avian navigation, in both homing and migration" (Yodlowski et al. 1977:226). Birds have been known to utilize transmission line corridors as travel lanes (Carothers and Johnson 1975:215, Grue 1977:214). During inclement weather could sounds produced by corona along a north-south running transmission line similarly aid nocturnal avian migrants?

Before concluding our discussion of AN we would like to mention one other topic which is important when considering the possible effect of AN on wildlife. Throughout this paper we stress that AN is only one component of a transmission line environment. The effects of AN then must be viewed in relation to the overall effects of the line. The combined effect of AN with effects from other transmission line parameters could take several forms. Possibilities for combined effects in such situations could be indifferent, additive, synergistic, or ameliorative (EPA 1974:E-3). The effect of relatively low level AN if it combined synergistically with the effect of another parameter could result in a greater effect than if AN were considered alone. Certain chemical agents, and certain vibrations can have synergistic effects when combined with noise (EPA 1974:E-5). In bird control work (Busnel and Giban 1968) felt the addition of a visual stimulus would enable lower sound intensities to be used when using sonic repellents. In the transmission line environment the effects of AN may combine with the electric and magnetic field synergistically.

THE EFFECTS OF TRANSMISSION LINES ON WILDLIFE

Although EHV transmission lines were first put into operation in the 1950's, it was several years before any work was done to systematically document the effect of these lines on wildlife. Passage of the "Environmental Policy Act of 1969" with its requirements that Federal agencies prepare environmental impact statements for all major projects pointed to the need for additional data for predicting environmental impacts.

One of the first attempts to assess the state of knowledge of the environmental impact of transmission lines was a colloquium, "Biotic Management Along Power Transmission Rights-of-Way" held at the University of Massachusetts in June 1973 (Goodland 1973). Another contribution which further defined the environmental impact of transmission lines was published a year later by the Oak Ridge National Laboratory (Kitchings et al., 1974). The most recent national event to provide a forum for discussing the impact of transmission lines on wildlife was a symposium on "Enviromental Concerns in Rights-of-Way Management", held in January 1976 at Mississippi State University (Tillman 1976).

Biological Research on the BPA Transmission System

Having briefly described the transmission line enviroment and potential sources of impact on wildlife we will now describe BPA research conducted to date. This research has provided information with which to begin assessing the possible effects of transmission line AN, and other parameters, on wildlife.

BPA is a Federal agency responsible for marketing the power generated by all Federal dams in the Columbia River Basin. BPA transmission lines are located in a wide variety of wildlife habitats including some of the most productive big game habitat in the U.S. In 1974 BPA developed a program to begin determining the effects of transmission lines on wildlife.

Idaho 500-kV a-c Transmission Line Study

The first research project developed in the BPA program was designed to determine the effects of a 500-kV transmission line on migrating Rocky Mountain elk (*Cervus canadensis nelsoni*) (Lee 1974). Concerns have been expressed that transmission lines could interfere with movement of migratory wildlife species (Villmo 1972, Martinka 1974, BPA 1974). Villmo (1972:8) reported that the unusual noise generated by power lines (no voltages or noise levels stated) seemed to frighten reindeer in Scandinavia. He stated that "When herders are attempting to move a reindeer herd across a power line which is generating noise we know that the reindeer react to the sound and are reluctant to pass under the lines" (Villmo 1972:8). He also said that in some cases it could not be determined whether the power line itself or the cleared right-of-way was alarming the reindeer.

BPA sponsored an intern with the Western Interstate Commission for Higher Education (WICHE) to conduct a 1-year study of the possible effects of a transmissiuon line on elk migration. The study was completed in June 1975 and was one of the first studies to systematically investigate and document wildlife behavior near a 500-kV line (Goodwin 1975, Goodwin and Lee 1975).

The study was designed to test the hypothesis that elk movement on, and use of a 500-kV transmission right-of-way, is no different than that occurring on other forest clearings. The study area was in northern Idaho along the BPA 500-kV line between Dworshak Dam and Hot Springs, Montana (Figure 1). The line is located in heavily forested areas of the western red cedar (*Thuja plicata*)/ western hemlock (*Tsuga heterophylla*) vegetation type.

Construction of the Hot Springs-Dworshak line began in July 1968 and was completed in October 1972. The line was engerized in March 1973. Voltage extremes on the line range from 500-550 kV. The steel, delta configuration towers average 37 m in height and are spaced approximately three per km. Three subconductor configurations are used on the line; the single, double and triple subconductor per phase forms. Audible noise characteristics for these configurations vary considerably (Figure 4).

The study was based on a comparison of animal movement on and use of the right-of-way with that on other clearings. Five paired right-of-way and control areas were used during the study. Study methods included direct observations, time lapse photography, track counts, and vegetation analyses. In addition to elk, the study provided information on several other wildlife species, and on the use of the right-of-way by hunters.

When an animal was observed in the right-of-way or control, an audible noise measurement in dB(A) was made under the outer conductor and the noise level at the animal's location was estimated. Estimates were made based on the knowledge that line noise attenuates at a rate of 3 to 4 dB for each doubling of distance (Perry 1972). Noise measurements were made with a General Radio Type 1551-C sound level meter. The 25 mm ceramic microphone was approximately .5 m above the ground when measurements were made. No measurements of the 120 Hz hum or other frequencies were made.

Between August and December 1974 a total of 310 hours was spent observing two paired right-of-way and control areas. Due to minimal use which the study areas received during this time of year and the nocturnal behavior of many animals, very few observations were made. Only 4 deer, 2 bear (*Ursus americanus*), 6 elk, and 22 coyotes (*Canis latrans*) were observed. From March to May 1975 less emphasis was placed on direct observations, however, several hundred deer and elk were seen while the observer was counting tracks and servicing time lapse cameras. The problems which limited the direct observations in the fall also applied to the time lapse cameras.

Typical behavior of most deer and elk when they entered the right-of-way or control was to remain motionless for a few moments at the forest edge. After this, they entered the clearing and usually began feeding. After initial wariness when entering a clearing none of the deer or elk observed appeared to be disturbed by the presence of the transmission line.

Results of the track counts indicated deer and elk movement across all forest openings during the fall was low, but increased steadily throughout the season. Elk movement particularly increased once snow began to accumulate. The tracks of 87 elk and 9 deer in the vicinity of the right-of-way were followed in the snow. Thirty-eight percent of the animals maintained a relatively straight line of travel as they approached, crossed, and left the right-of-way. Sixty percent of the animals followed roads or established game trails in crossing the right-of-way. Only 2 percent failed to cross the right-of-way. In these two cases elk came within 25 m of the right-of-way and appeared to have

come to the area to feed.

Generally the right-of-way and control areas had significantly greater ground cover than the adjoining areas. The percentage of grasses, forbs, and shrubs sometimes differed considerably between right-of-way and control.

Fair weather AN on the right-of-way for the single conductor per phase configuration ranged from 45 to 55 dB(A). Levels of 62-68 dB(A) were measured during rain. For the two conductor per phase configuration, maximum fair weather AN was 35 to 40 dB(A). AN from the three conductor per phase configuration was usually less than 30 dB(A). A reading of 52 dB(A) was recorded on the right-of-way during a light shower. AN measured in the control areas was usually below 30 dB(A). The highest reading in a control area was 44 dB(A) which was during a light rain.

During several days of 55 to 60 dB(A) noise levels, deer and elk track counts did not indicate any aversion by the animals to the right-of-way. The study was not specifically designed to provide quantitative data on the possible effects of the line on birds, however, ravens, grouse, and several other bird species were observed near the line when noise levels exceeded 60 dB(A). During the study a herd of approximately 60 bighorn sheep was observed in the Dworshak-Hot Springs 500-kV right-of-way near Hot Springs, Montana. During a light rain with AN of 53 dB(A) the sheep were observed bedded down on the right-of-way.

The activity of hunters on the right-of-way and access roads had a significant influence on elk movement. Although segments of the right-of-way were closed by locked gates, some hunters broke the gates in order to drive onto the right-of-way. Many persons hunted the right-of-way on foot and some used motorcycles. Hunting pressures had a definite effect on elk distribution. Elk moved away from hunting pressure and concentrated in places 0.8 km or more away from roads and clearings.

Data obtained during the Idaho study indicated that elk movement near the 500-kV transmission line right-of-way was not significantly different than that near other forest openings. The transmission line produced audible noise levels which at times were very annoying to humans. There was no indication, however, that the noise deterred elk, deer and several other wildlife species from entering and crossing the right-of-way. Elk and deer use of the right-of-way and control areas was primarily a function of available forage.

Elk and deer avoided the right-of-way and control clearings during the hunting season. The transmission line, however, did not appear to prevent these animals from eventually crossing the right-of-way and continuing their migration.

1100/1200-kV Transmission Study

In April 1976 another BPA-sponsored biological study began. This one is being conducted at the site of the BPA 1100/1200-kV prototype transmission line near Lyons, Oregon (Figure 6). This 31-month long study is being conducted by Battelle-Northwest of Richland, Washington.

During the Environmental Impact Statement process for the 1100/1200-kV project, questions were raised as to the possible biologic effects of such a line (BPA 1976b). No significant adverse biologic effects are expected. However, because of the concerns which were raised, and because few scientific studies have been conducted for existing transmission lines, BPA decided biological studies would be an integral part of the prototype project.

Construction of the 2.1 km long line began in the spring of 1976 and was completed the following fall. The line was constructed on a right-of-way which had contained three 230-kV transmission lines. One of the 230-kV lines was removed and the 1100/1200-kV was constructed in its place and relatively little tree clearing was required. The first of three transformers was energized December 21, 1976. All three phases were energized on May 10, 1977.

The prototype line is providing a source of data for evaluating the steady-state electrical effects of 1100/1200-kV including AN, radio and television interference, electrostatic effects, and effects on other utilities.

Transmission lines of 1100/1200-kV can be designed so electrical effects (i.e., maximum ground level electric field strength, AN, and oxidant production) are not significantly different from 500-kV lines. This requires the use of towers averaging 61 m in height and 8 subconductors for each phase. Each subconductor is 4.1 cm in diameter. A lateral profile of AN calculated for the 1100/1200 kV line is shown in Figure 7. The prototype line has been designed so that in two locations within a fenced study area, electric field strength could approach 14 kV/m. Other than possible damage to some trees which have purposely been left quite near the line, these higher field strengths are not expected

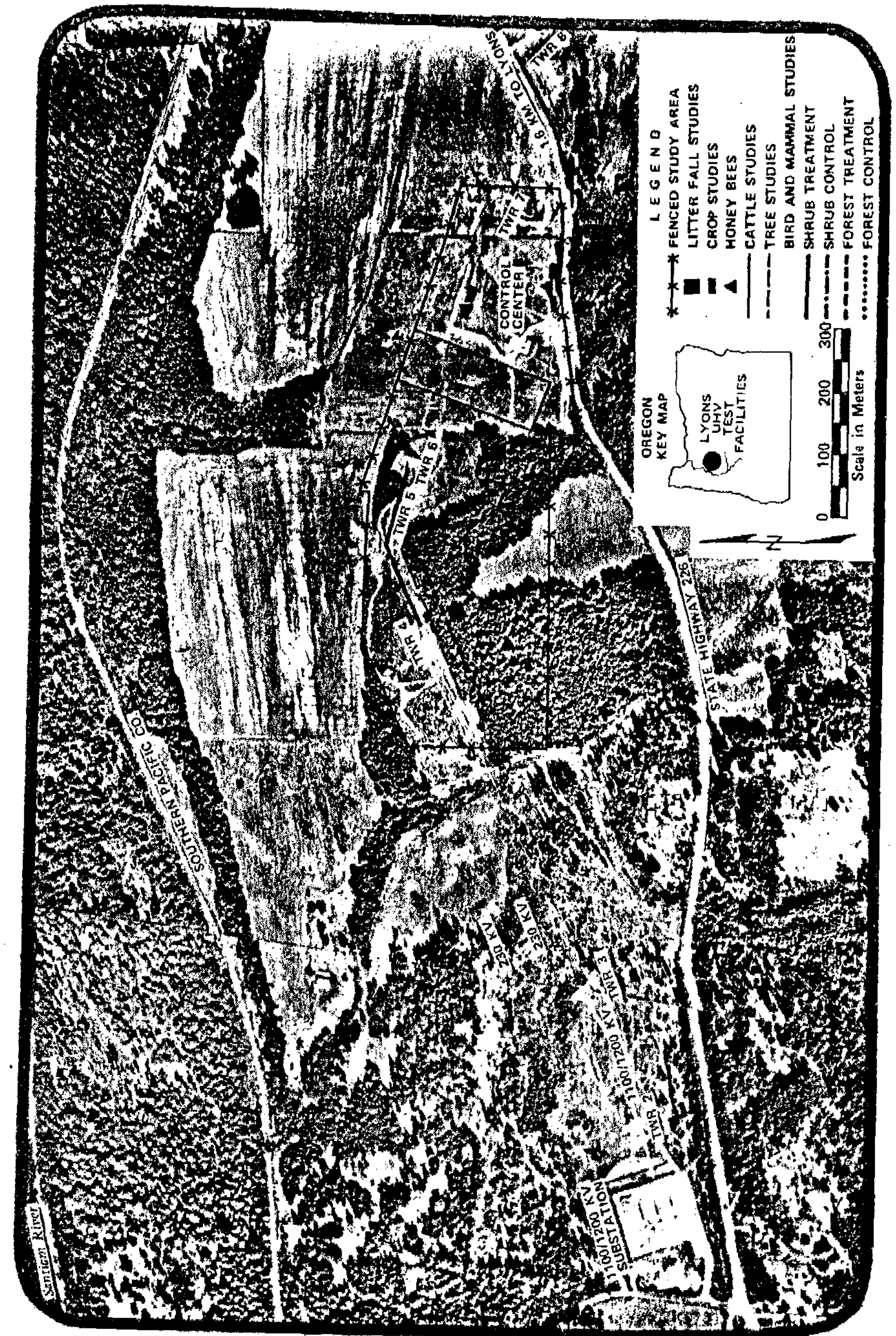


Figure 6 - The Bonneville Power Administration Lyons U.H.V. Test Facilities showing location of biological study areas.

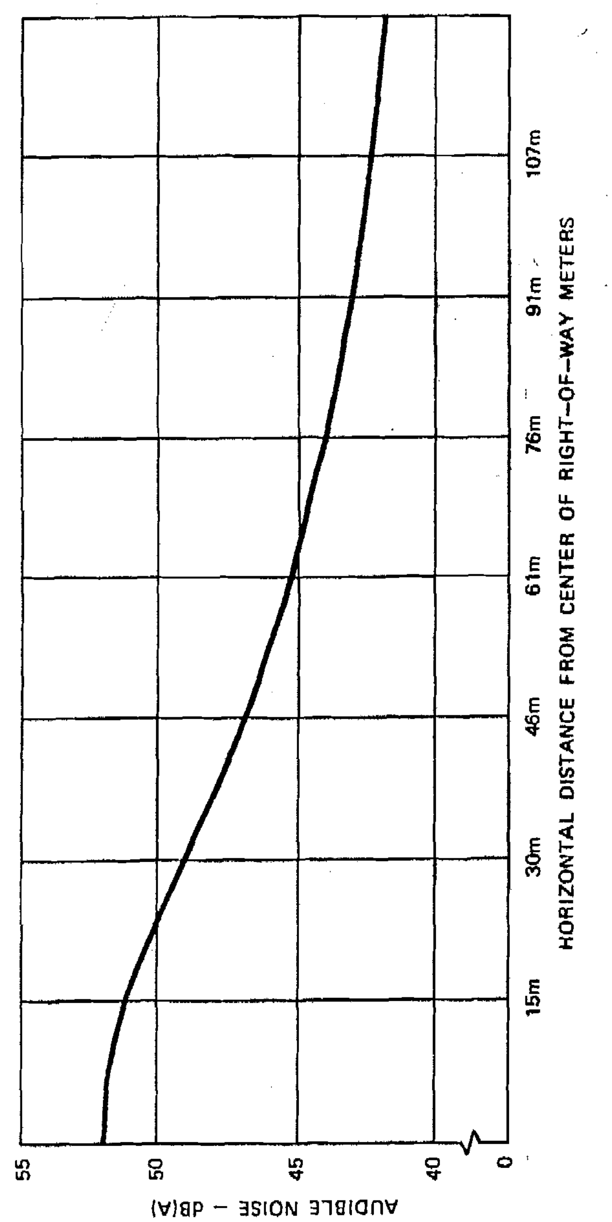


Figure 7 - Lateral profile for calculated mean audible noise for the B.P.A. 1100/1200 kV Prototype Transmission Line with eight 4.1 cm diameter conductors per phase. Adapted from Biological Studies Task Team

to result in any adverse biologic effects. By using these higher levels, however, the potential for threshold effects occuring just above design limits of 9 kV/m can be evaluated.

Biological studies at the 1100/1200-kV site include natural vegetation, crops, wildlife, cattle, and honey bees (Lee and Rogers 1976). From April to December 1976 pre-energization biological data was obtained with which to identify possible effects occurring after engerization. The general study approach after energization is to compare plants and animals on the 1100/1200-kV right-of-way with those in nearby control areas.

Total abundance and species diversity are the two main parameters which will be used to evaluate possible effects on bird populations. Observations of flight and feeding behavior will also be made. Birds inhabiting the study area are sampled along transects in four areas consisting of two treatments (right-of-way) and two controls (Figure 6). Birds seen, or heard within a radius of 20 m are counted during early morning surveys on three consecutive days.

Two hundred small mammal live traps are located along the same transects used for the bird studies. The traps are set for three consecutive nights and captured animals are marked with a unique toe clip pattern. Information on weight, approximate age, and reproductive condition is recorded each time an animal is captured.

Honey bees are being used as an indicator species to evaluate possible effects on insects. Honey bee studies take place during the spring and summer of 1977 and 1978. Six colonies are placed beneath the 1100/1200-kV line, and six away from the line (Figure 6). Parameters selected for study are honey and wax production, mortality, swarming tendencies, foraging, and general behavior. This phase of the study will complement a similar honey bee study sponsored by the Electric Power Research Institute (EPRI) which is being conducted beneath a 765-kV transmission line (Kornberg 1976).

Results of the biological studies, along with results of economic and engineering studies will provide the basis for a decision on whether to adopt 1100/1200-kV transmission in the BPA system. At the time this paper was written only a small amount of post energization biological data had been collected at the 1100/1200-kV test site.

Preliminary analysis of pre-energization bird data shows that although more birds were observed in the control areas than in the treatment areas, the differences were not statistically significant (Rogers 1977). Analysis of post-energization bird and mammal data will be done when sufficient data has been accumulated. No obvious adverse effects on bird and mammal populations have as yet been identified which could be attributed to AN or other operational parameters of the 1100/1200-kV line. During this time maximum line voltage was 1100 kV. Beginning in the summer of 1977 the line will be operated at 1200 kV during certain intervals. Preliminary measurements made since energization of the three phase 1100/1200 kV prototype line indicate the amount of AN produced by the line is within ± 2 dB of the calculated values shown in Figure 7.

Although very little foul weather AN data has as yet been obtained for the 1100/1200 kV line, preliminary measurements point out again that line design e.g., number and diameter of conductors, and not just line voltage alone determines the AN characteristics of a transmission line.

Only on a few occasions have behavioral responses been observed in animals which appeared to be a response to the electrical parameters of the 1100/1200-kV line. Shortly after the first phase of the line was engerized an American kestrel (Falco sparverius) attempted to land on an energized conductor. The bird approached to within approximately 30 cm of the conductor and after a few attempts at landing it finally flew off. The bird later landed on one of the un-energized phases of the 1100/1200-kV line. When all three phases of the 1100/1200 kV line were first energized the five head of cattle in the test pen were lying down almost directly under the line. When the line was energized there was a moderate amount of AN and four of the cattle immediately rose to their feet. After a few minutes two of the cattle laid down again near the line and the others began grazing nearby (John Hedlund, personal communication).

No behavioral effects have been noted in the honey bee colonies under the 1100/1200 kV line which could be attributed to operation of the line.

More data will be required to properly assess the possible biologic effects of the 1100/1200 kV line. Biological studies at the prototype site will continue through August 1978.

HVDC Transmission Line Biological Study

Relatively few d-c transmission lines have been constructed throughout the world. One of the first and longest d-c lines built is the Celilo-Sylmar ± 400 kV d-c line which extends from The Dalles, Oregon to Los Angeles, California (Figure 1). A literature review failed to identify any biological studies which had been conducted on a d-c transmission line right-of-way. With planning underway for a possible second d-c intertie line, BPA developed a program to study the effects of the existing Celilo-Sylmar d-c line (BSTT 1976). A 13-month long study began in June 1976. The BPA sponsored study is being conducted by the junior author. The d-c biological study includes natural vegetation, crops, wildlife, and domestic animals.

Although at various times observations were made along the entire Oregon portion of the d-c line, two primary areas were selected for intensive study. One was located in the Western juniper (Juniperus occidentalis) vegetation zone and the other in the big sagebrush (Artemisia tridentata) zone. Almost 90 percent of the Celilo-Sylmar d-c line in Oregon is located within these zones. Field studies were conducted from mid-June 1976 through January 1977, and from May through mid-June 1977. Because data analysis was not complete as this paper was written only preliminary results are presented here. We feel this is warranted because to our knowledge this was the first biological study of a d-c transmission line conducted in the U.S., and the measurements of AN made during the study are among the first to be reported for the Celilo-Sylmar d-c line which were made over an extended period of time.

Power is transmitted on the Celilo-Sylmar ± 400-kV d-c transmission line via a negative and positive pole each of which consists of two 4.56 cm diameter subconductors. The subconductors are strung on steel self-supporting or guyed aluminum towers which are typically 36 m tall and 12 m wide at the crossarms. Ground clearance to the conductors varies from approximately 25 m at the towers to approximately 13 m at midspan depending on site characteristics. Tower spacing averages 2.9/km. A single overhead ground wire runs the length of the Oregon portion of the d-c line. A light duty maintenance road parallels the line approximately 15 m from the center of the right-of-way. Distribution of ground level electric field strengths for the d-c line is generally assymetrical and varies widely due to the pronounced effect of wind on space change distribution (Bracken et al., 1977). At no time during the study did we notice any effects which indicated we could perceive the d-c fields.

Relatively few AN measurements had been made for the Celilo-Sylmar d-c line when this study was initiated although AN was measured during studies conducted with the d-c test line at The Dalles, Oregon (Hill et al., 1977). At various times during this study measurements of AN were made on the right-of-way and in control areas. These were made with a Bruel and Kjaer Type 2204 sound level meter with a 25.4 mm condenser microphone. With this microphone the meter had a range of 15-140 dB(A). The meter was fitted with an octave filter set with 10 center frequencies from 31.5 Hz to 16000 Hz. All measurements were made with the meter mounted on a tripod with the microphone in a vertical direction (perpendicular to the conductors). The microphone was covered with a polyurethane sponge windscreen when measurements were made. AN levels measured on the d-c transmission line right-of-way were generally lower and more variable than that reported for a-c lines of comparable voltage. Increases in AN above ambient for the d-c line ranged from essentially 0 up to 20 dB(A) with most measurements in the 0-10 dB(A) range. The highest AN level measured on the d-c line right-of-way during the study was 38 dB(A) which is probably about the maximum expected.

For wildlife studies emphasis was on songbirds, raptors, small mammals, mule deer (Odocoileus hemionus), and pronghorn antelope (Antilocapra americana). For purposes of this paper, only preliminary data from the songbird studies will be considered in detail. Songbirds were sampled using a circular plot technique. All birds seen and heard from fixed points were counted during early morning hours at 0.4 km intervals along 3.6 km long transects. The distances of the birds from the observer were measured with a rangefinder which had an upper limit of 219 m. Distances to birds further than this were estimated. In addition, the position of each bird was noted as being in one of eight 45 degree sections centered on the observer. During the 1977 spring sampling period this method was modified. A bearing was taken on each bird so that the distance of each bird from the center of the d-c line right-of-way could be estimated. In addition the length of the transects in the sagebrush study area was lengthened to 5.6 km with 15 stations. In the sagebrush study area, one transect was located on the center of the d-c line right-of-way and another in a control area parallel to the right-of-way and approximately 800 m away. In the Western juniper study area, a transect was established along a road which paralleled the right-of-way and was 400 m away. This was in addition to the right-of-way and control transects. In each study

area songbird sampling was conducted on alternate days until a total of four days was completed for each transect for each of three sampling periods.

During the 1976 songbird sampling period, a possible sampling bias introduced by the effects of transmission line AN on the observer was identified. Subjectively, it seemed that AN of certain levels and quality might function to: (1) increase the ambiguity of species identification, (2) mask detectability of bird calls, or (3) bias distance estimation to those birds which were only heard. Since 50-80 percent of birds detected on right-of-way and control transects were heard but not seen these sources of bias could affect the indices to songbird abundance and distribution obtained from the censuses.

Sagebrush habitat, where transmission line construction effects on vegetative structure are the least obvious, present the best field situation for examining the possible sources and magnitude of these biases. Even so there were differences in vegetation on the right-of-way compared with the control areas. In the control as compared to the right-of-way, big sagebrush occurred with slightly greater frequency, and the mean height and percent of total cover was slightly greater. On the right-of-way green rabbit brush (Chrysothamnus nauseosus) and grasses accounted for a significantly greater ($P < 0.05$) proportion of total cover than on the control.

In 1976 and 1977 the total number of birds detected on the right-of-way transects was respectively 76.2 percent and 75.2 percent of the total number detected on the control transects. Unknown species of birds were not counted during 1976. In 1977 unkown species accounted for 13.7 percent of the total number of birds detected on the right-of-way transects and 12.4 percent of the total number of birds detected on the control transects. This difference of 1.3 percent was not statistically significant at the 0.05 probability level.

In 1977 the distances to birds heard but not seen were classed as close, medium or far. These classes corresponded to distances of less than 100 m, 100-200 m, and greater than 200 m, respectively. The four most abundant species of songbirds were tabulated, considering only those birds heard, into these classes (Table 4). The species were arranged in a subjective ranking of song volume with the sage thrasher the loudest and the horned lark the quietest.

Table 4. Percentage Distance Distribution of Birds Heard Only, On Control and Right-of-Way (ROW) Transects in Sagebrush Habitat Along the ± 400 kV d-c Transmission Line in Central Oregon

Species	Transect	Distance		
		Close 1/	Medium 2/	Far 3/
Sage Thrasher (Oreoscoptes montanus)	Control	16.8	57.1	26.1
	ROW	14.4	57.7	27.8
Sage Sparrow (Amphispiza belli)	Control	42.9	55.7	1.4
	ROW	35.4	60.8	3.8
Brewer's Sparrow (Spizella breweri)	Control	72.3	27.7	0.0
	ROW	61.1	38.9	0.0
Horned Lark (Eremophila alpestris)	Control	87.0	13.0	0.0
	ROW	91.7	8.3	0.0

1/ Less than 100 m
2/ 100-200 m
3/ Greater than 200 m

There was little difference between right-of-way and control distributions (Table 4) for the loud sage thrasher. For the sage sparrow and Brewer's sparrow respectively, approximately 5 percent and 11 percent more birds were classed in the medium distance category for the right-of-way transects compared to the control. This could indicate that AN from the transmission line was biasing distance estimates. Analysis of the distance distribution from the transect centerlines for birds seen, however, showed that the mean distance was slightly greater, though not statistically significant, for both sage sparrows and Brewer's sparrows on the right-of-way compared to the control. The increased frequency of these birds in medium and far categories may reflect actual distribution patterns rather than AN bias on the observer.

Horned larks present a somewhat different case. Their call and song is weak in comparison to the other birds in Table 4. It seems that the approximately 5 percent lower frequency of horned larks classed in the medium distance category on the right-of-way may reflect masking of this species' call by certain levels and quantities of AN from the transmission line.

If the AN from the transmission line markedly affected the total number of birds detected on the right-of-way we might expect the percent of total birds that are heard but not seen to be greater on the control transects as compared to the right-of-way. Some ambiguity in this relationship might be introduced by the fact that a number of the birds seen are first detected by auditory means.

In 1976, 79.9 percent of the total birds detected on the right-of-way were heard only and 71.5 percent of the total birds detected on the control transects were heard only. In 1977, 67.0 percent of birds detected on the right-of-way transects were heard only and 67.6 percent of birds detected on the control transects were heard only. In neither year was the difference between percent heard only on right-of-way and control transects significantly different.

The bias of AN on songbird detection on the ± 400 kV d-c transmission line right-of-way does not then appear to be of great enough magnitude to account for the approximately 25 percent lower number of birds detected on the right-of-way transects. Positive identification of this bias may have been obscured by the variable character of the AN from the d-c line. At each right-of-way transect station in 1977 the AN from the d-c line was classed into one of four categories: (1) no line AN perceived, (2) line AN perceived but of minor interference in songbird detection, (3) line AN perceived and of moderate interference in songbird detection, and (4) line AN perceived and of major interference in songbird detection. For the 60 transect stations (4 daily transects with 15 stations each day) the distribution of the AN into the above four subjective categories was:

category 1, 17 stations
category 2, 12 stations
category 3, 17 stations
category 4, 14 stations

We feel that AN bias becomes a more important consideration at higher transmission line AN levels than measured for the d-c line. The bias may be more subject to identification on a-c lines where AN is of generally higher levels and

Wildlife Observations Near Two 500-kV Transmission Lines

As described above, during the study of the d-c transmission line we identified possible effects of AN that may affect an observer's ability to detect songbirds on the right-of-way. The possibility that AN may also affect songbird distribution was also raised.

To obtain additional information on these possibilities, the senior author made observations along the right-of-way of two 500-kV a-c transmission lines in south central Oregon. These lines, Grizzly-Malin, run generally north and south and in places are near to the Celilo-Sylmar d-c line (Figure 1). These lines were constructed and energized during the late 1960's. The lines consist of steel "delta" towers and each phase is strung with two 4.07 cm diameter subconductors. Both lines have two overhead ground wires for lightning protection. An access road runs between the two lines. The two parallel sets of towers are approximately 50 m apart.

The observation period (June 5-June 8, 1977) was timed to coincide with similar field observations being conducted on the d-c line. Two 3.6 km long sample transects were established. One was along the center of the right-of-way and the other was 525 m west and parallel to the lines. The study area was approximately 129 km south of Grizzly Substation (Figure 1). Topography of the study area was fairly level and was in the big sagebrush vegetation type. We chose the particular site because it was one of the few areas along the right-of-way located completely in sagebrush. We felt that the possible effects of AN would be more apparent in such an area where relatively little difference in vegetation existed between the right-of-way and adjacent areas.

Sample methods employed were similar to those utilized in the d-c transmission study. In addition to birds counted at 10 stops along the transects, birds seen and heard between stops were also counted. The stops provided an opportunity to observe bird behavior under differing AN levels.

The location of each bird seen or heard was recorded by noting both the angle and distance of the bird from the observer. A range finder with an upper limit of 180 m was used to measure distances. A metal plate marked in degrees and fitted to a tripod on which was mounted a 10x spotting scope was used to determine bearings.

Counts began within one-half hour after sunrise. One transect was usually completed by about 0900 hours and then

counts were made on the other transect while returning to the starting point. The second transect was usually completed by about noon. Counts were conducted on four consecutive days beginning June 5. The transects were alternated so that two early and two late morning counts were conducted for each transect.

AN measurements were made each day at about sunrise before the counts began and then again after both transects had been completed. At both times measurements were made on and off the right-of-way. Measurements were made with the Bruel and Kjaer type 2204 sound level meter which was described above. The meter was tripod mounted which put the microphone about 1.5 m above the gound plane. Measurements on the right-of-way were all made at the same point which was mid span between two particular towers. The meter was placed directly under conductors and the distance from the microphone to the conductors was 11 m.

Figure 8 shows how AN levels varied between the right-of-way and in the control area during the sample period. During fair weather AN measured on the right-of-way averaged approximately 15 dB(A) higher than in the control area. With wet conductors there was about a 20 dB(A) difference between the two areas. The levels are for periods of minimal wind and/or bird calls. We feel this best depicts the AN produced by the lines in comparison to the relatively quiet surroundings of the study area. Wind or birds would at times produce sound level meter readings in the control area which equaled or exceeded readings on the right-of-way.

Although most AN measurements were made only on the right-of-way or in the control area, on the night of June 4 measurements were made at two lateral distances near the 500-kV lines. With AN on the right-of-way at 46 dB(A) and 19 dB(A) in the control, 40 dB(A) was measured 25 m west of the outermost conductors, and 36 dB(A) at 50 m.

During the sample period the 500-kV lines were always audible on the right-of-way transect and frequently from the control even during fair weather. This is in contrast to the more intermittent AN from the d-c line.

Although some birds were detected at distances up to 200 m or more from the center of the right-of-way, AN from the two 500-kV lines was sufficiently loud to cause some ambiguity in the ability of the observer to detect birds by their calls. The problems did not appear to be so much re-

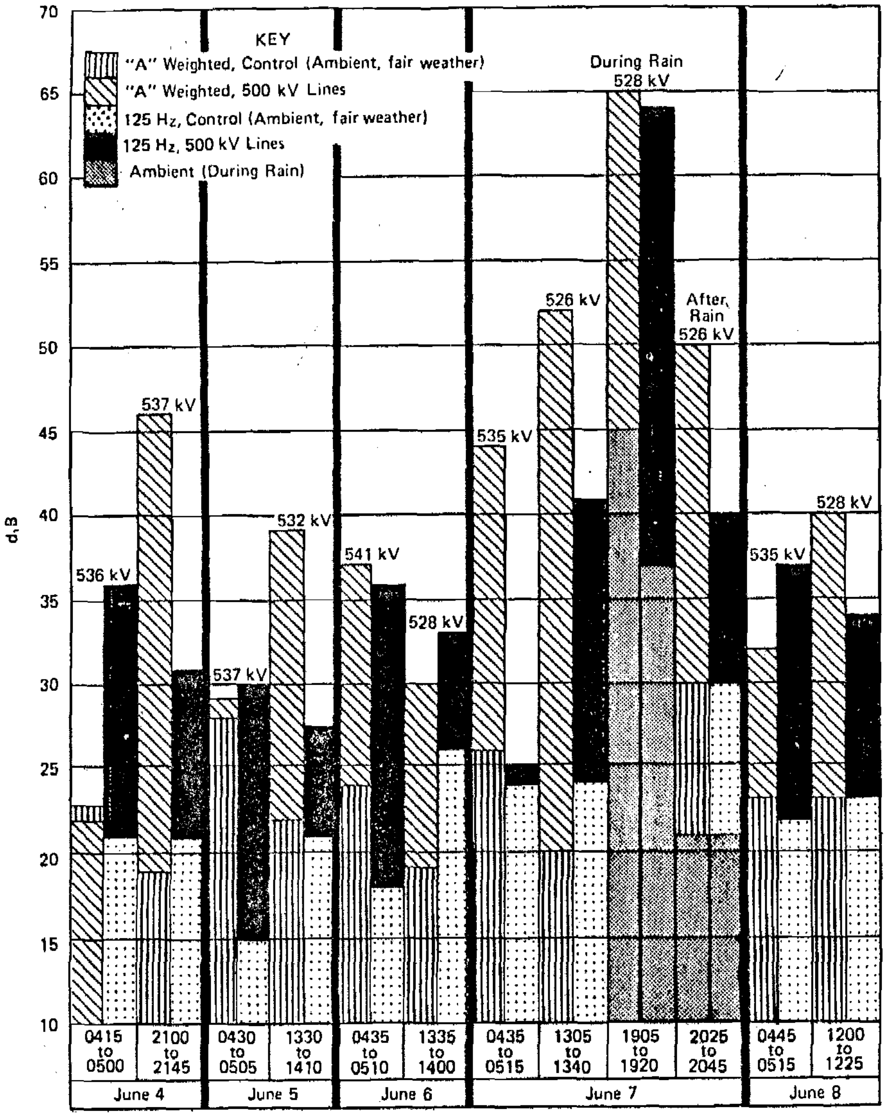


Figure 8 - Audible noise measured during June 1977 on the right-of-way of two 500 kV a-c transmission lines (Grizzly-Malin) as compared with a control area 525 m away from the line. During rain ambient noise was also measured 1.6 km away from the line. For the times shown above each day, the dB value at the top of each keyed bar pattern represents the average noise level measured during an approximate 3 minute period with essentually no wind. The line voltage during the measurement period is shown indicated in kV.

lated to hearing and locating birds by their songs but short, weak calls (e.g., cheeps, tweets) were sometimes difficult to locate when AN was originating from lines on either side of the observer. This effect, first noted on the d-c line, was more apparent with higher AN of the a-c lines.

In an attempt to eliminate some of the bias caused by the AN, we have tabulated only birds seen and heard within 75 m on either side of the right-of-way. In the field, it appeared the AN was not significantly affecting the observers ability to detect birds within this distance. Figure 9 shows the distribution of birds seen and heard during the four sample days within the 150 m wide transect on the right-of-way and in the same size transect in the control. As determined by a t-test for two sample means there was no significant difference in the mean distance of detected birds from the center of the right-of-way transect compared with the control. The relatively high number of birds detected near the center of the transects is in part due to birds being flushed by the observer.

Another explanation for the large number of birds observed in the center of the right-of-way may be possible effects of the access road. Birds along the road may have been more easily detected visually. On several occasions birds appeared to be attracted to the edge of the road. Even though the road was only 6 m wide the "edge effect" may have been a factor contributing to the greater number of birds near the center of the right-of-way. Additional information to evaluate this possibility could be obtained by conducting a count along a road near the transmission line which is of a similar width and which receives similar travel as the right-of-way. During the study period no vehicles were seen using the access road. On the weekend prior to the study a number of motorcyclists were observed using the access road and other roads in the area.

Although the detected birds appeared to be similarly distributed within the two transects, there was a statistically significant difference ($P < 0.05$) in the total number of birds detected in the two areas. Table 5 gives the total birds detected on each day for both seen and heard birds. Table 6 lists the bird species counted.

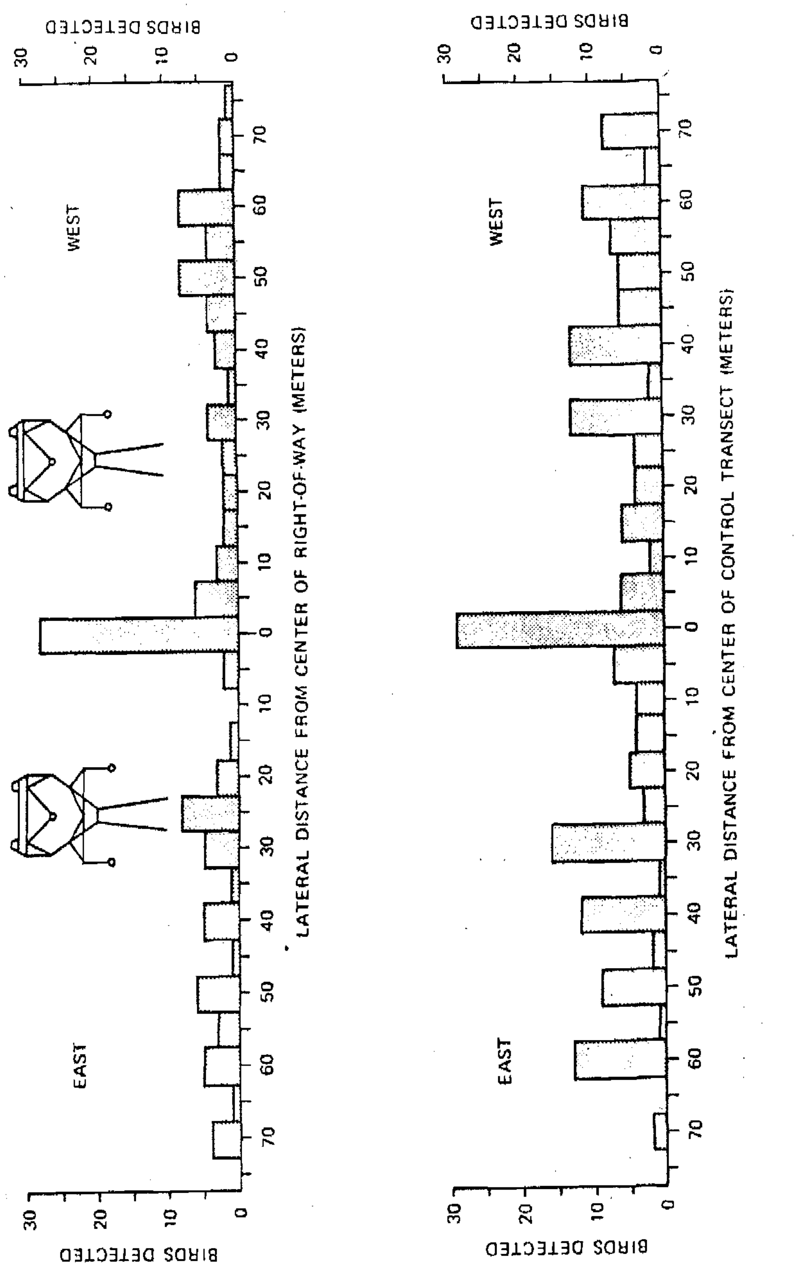


Figure 9 - Distribution of birds seen and heard during morning counts along a 150 m wide, 3.6 km long transect along the right-of-way of two 500 kV transmission lines and along a similar size control transect parallel to the right-of-way and 525 m west.

Figure 9 (continued) - Counts were made June 5-8, 1977 in south central Oregon in Big Sagebrush (Artemisia tridentata) vegetation type.

Table 5. The total number of birds seen and heard only, along 3.6 km long, 150 m wide transects during morning counts from June 5-8, 1977. One transect was on the right-of-way of two 500-kV transmission lines and the other was parallel to the lines and 525 m away.

Day	Control Transect			Right-of-way Transect		
	Birds			Birds		
	Seen	Heard only	Total	Seen	Heard only	Total
June 5	43	2	45 1/	19	5	24
June 6	28	23	51	25	8	33 1/
June 7	31	32	63 1/	22	6	28
June 8	19	20	39	29	11	40 1/
Totals	121	77	198	95	30	125

1/ These counts are for the early morning sample which began one half hour after sunrise. The other counts were then conducted from about 0900-1200 hours.

Table 6. Species distribution of birds seen and heard along 3.6 km long, 150 m wide transects during morning counts from June 5-8, 1977. One transect was on the right-of-way of two 500-kV transmission lines and the other was parallel to the lines and 525 m away.

	Control		Right-of-way	
Species 1/	Number Detected	Percent of Total	Number Detected	Percent of Total
Brewer's Sparrow (*Spizella breweri*)	97	49	46	36
Sage thrasher (*Oreoscoptes montanus*)	15	7.6	18	14.4
Sage sparrow (*Amphispiza belli*)	18	9.1	19	15.2
Horned lark (*Eremophila alpestris*)	6	3	0	0
Meadow lark (*Sturnella neglecta*)	0	0	1	0.8
Loggerhead shrike (*Lanius ludovicianus*)	0	0	4	3.2
American kestrel (*Falco sparverius*)	0	0	2	1.5
Mourning dove (*Zenaidura macroura*)	0	0	2	1.5
Unknown 2/	61	30.8	34	27.2
Total	198		125	

1/ The right-of-way also contained a raven nest with four young on a tower.
2/ Most of the birds in this category were probably either Brewer's sparrows or Sage sparrows.

Of particular interest in relation to AN bias is the ratio of birds that were heard only to the number seen which were not heard first. For the control transect this heard/seen ratio was 0.64 compared to 0.32 for the right-of-way. This indicates a noticeably greater proportion of auditory detections on the control transect. In addition, many birds that are eventually seen are first heard. AN then may also bias visual detections as well. On the control transect 44 percent of the birds seen were heard first and on the right-of-way the corresponding percentage was 35.

Assuming the AN did bias bird detectability, heard/seen ratios and the percent of seen birds that were heard first on the control, can be used to derive an estimate of the degree of bias present. We have calculated that in the present example, the bias introduced by AN could account for as much as 75 percent of the difference in total birds detected between the right-of-way and control transects. These calculations were based on the number of birds seen and not heard first on each transect. For these birds that were seen only, there was only 9 percent fewer detected in the right-of-way as compared to the control.

The magnitude of this bias would most likely vary among species due to differences in song volume and calling rates. The above calculations assume the same rate and intensity of bird vocalizations between the right-of-way and the control. AN could cause an increase in the frequency of calling rates similar to that reported by Potash (1972). This could function to lower the percentage of the difference in birds detected between right-of-way and control which could be accounted for by the AN bias.

Vegetation differences could in part be responsible for the remainder of the observed differences between right-of-way and control transects. Vegetation composition and distribution has consistently been shown to be an important factor which influences bird distribution (Tomoff 1974, Balda 1975). Although no quantitative measurements of vegetation on the right-of-way and control transects were made, in general the shrub density appeared to be very similar between the two areas. Noticeable exceptions included the bare, unsurfaced access road (approximately 6 m wide) on the right-of-way and areas near some towers which had apparently not completely revegetated since construction. This reduction in shrubs available for singing perches and feeding areas could cause some reduction in density.

Grue (1977:130) believed that removal of nesting and foraging habitat was a primary factor responsible for lower densities of breeding birds on the right-of-way of two 500-kV transmission lines in the desert shrub habitat in Arizona. Grue also counted birds heard and seen during his study although he did not believe AN from the lines biased his ability to detect birds by sound (Grue, personal communication).

Another possibility for the lower densities is that the transmission line itself including the electric field and/or audible noise caused some birds to avoid the right-of-way. Grue (1977) also suggested that these factors were at times responsible for lower bird densities on the right-of-way of two 500-kV lines in Arizona. On numerous occasions during the census counts, birds were observed perched and singing directly under the conductors during conditions of highly noticeable AN. Several other birds were observed flying across the right-of-way near the conductors. No unusual animal behavior was observed which obviously suggested an aversion to the right-of-way by birds which could be directly attributed to the AN or the electric field of the 500-kV lines.

An afternoon thunderstorm on June 7 provided an opportunity to make additional observations during a period when high levels of AN were being produced by the lines (Figure 8). Shortly after the rain began observations were made along the portion of the right-of-way containing the census transect. A golden eagle (Aquila chrysaetos) and a red-tailed hawk (Buteo jamaicensis) were observed perched on towers. The birds appeared to be seeking shelter from the storm. Although a golden eagle was seen flying from one of the towers the following morning, during the rain storm was the only other time during a 6-day stay near the lines that these species were seen on the towers.

There was a raven (Corvus corax) nest on one of the towers in the study area which contained four fully feathered young birds. While it was raining AN of 64 dB(A) and 69 dB for the 125 Hz frequency was measured at a point on the ground midway between the tower with the nest and the adjacent tower.

AN on the right-of-way after the rain measured between 52-56 dB(A). The sound of the two lines was like loud rushing water. Birds began singing again when the rain stopped. "Bits and pieces" of bird songs could be heard through the noise. In the only span checked, 6 birds, 2 jack rabbits and fresh (less than one hour old) coyote tracks, were seen all within 40 m from the center of the right-of-way. One of the birds, a sage thrasher, was perched and singing just beyond an outer conductor. The noise was so loud that the bird could just barely be heard from less than 60 m away. These observations of wildlife utilization of the right-of-way under high AN conditions shows that the AN was not causing birds and some other species to completely avoid the right-of-way.

We feel that the difference in numbers of birds detected on the right-of-way of the two 500-kV transmission lines as compared to the control can largely be explained by the negative bias of AN on the observer. The degree of this bias is probably partly determined by the hearing acuity of the observer. However, more intensive studies are needed to obtain more definitive information with which to evaluate our preliminary findings. The possibility that AN or the electric or magnetic field or other factors were affecting birds on and near the right-of-way to some degree cannot be ruled out. One possibility for obtaining more definitive information on the bias due to AN would be for the observer to wear ear plugs when conducting counts on both right-of-way and control transects. One problem, however, is that relatively few birds are detected solely by visual means. By completely eliminating hearing as a means of detecting birds the number of birds sampled would be extremely low. The effects of low sample sizes would then add to the difficulty of testing for differences between the right-of-way and control areas. To determine what levels of transmission AN mask bird calls and songs of various birds at varying distances from an observer, tape recorded sounds could be used in both laboratory and field situations.

Transmission Line Raptor Study

Preliminary work with raptors during the d-c transmission line study led to the development of a project to obtain information on the effects of other BPA transmission lines on this group of birds (Lee 1976). Until recent years, the effects, both beneficial and adverse, that transmission lines have on raptorial birds have not received a great deal of study.

Part of the BPA raptor study involves obtaining information with which to determine how extensively transmission line structures are utilized as raptor nesting sites. For purposes of this study raven nests are also being counted. Information is being obtained in an attempt to answer such questions as: 1) which bird species are nesting on transmission structures? 2) where are nests located on various type structures? 3) what site characteristics determine whether transmission line structures are utilized for nesting sites? 4) does the electrical and acoustical environment within transmission towers have an effect on nesting birds? 5) how much annual raptor production occurs on BPA transmission line structures?

Birds nesting on EHV towers are exposed to AN and electric and magnetic field levels which greatly exceed those found at ground level. This provides an opportunity to study the possible effects of these parameters on adult birds and their young.

BPA is also installing a small number of artifical raptor nest platforms to evaluate their effectiveness in reducing maintenance problems caused by bird nests located over conductors. The feasibility of providing more desirable nest sites for large raptors is also being studied. The nest platform being installed was designed by Morlan Nelson and the Idaho Power Company (Nelson and Nelson 1976).

On April 1. 1977 helicopter patrol observers began collecting information on nesting raptors. Table 7 shows the preliminary data collected for EHV lines through May 1977. It appears that many of these nests are successfully producing young birds although this information is still being developed. A much larger number of nests are located on 230-kV and lower voltage BPA transmission lines and this information is also still being compiled.

Many of the nests on 500-kV lines are located on delta configuration towers. Figure 10 shows a delta tower and gives electric field strength and AN levels in some of the locations where birds are known to perch and nest. It should be pointed out that electric field measurements were made with a meter designed to measure in uniform field areas such as on the ground beneath a transmission line. The electric field in the tower is actually perturbed by the metal structure so the measurements in Figure 9 are only approximations. AN levels were calculated by Mr. Vern Chartier of BPA based on the work of Perry (1972) and on his own work with 765-kV lines.

As shown in Figure 10 during rain AN within the 500-kV tower strung with a single 6.35 cm conductor for each phase could reach 76 dB(A) or more. Most 500-kV lines in the BPA system utilize either the double or triple conductor bundle.

Table 7. Number of bird nests observed on BPA 500-kV a-c and ± 400-kV d-c transmission line structures during helicopter patrol flights in April and May 1977.

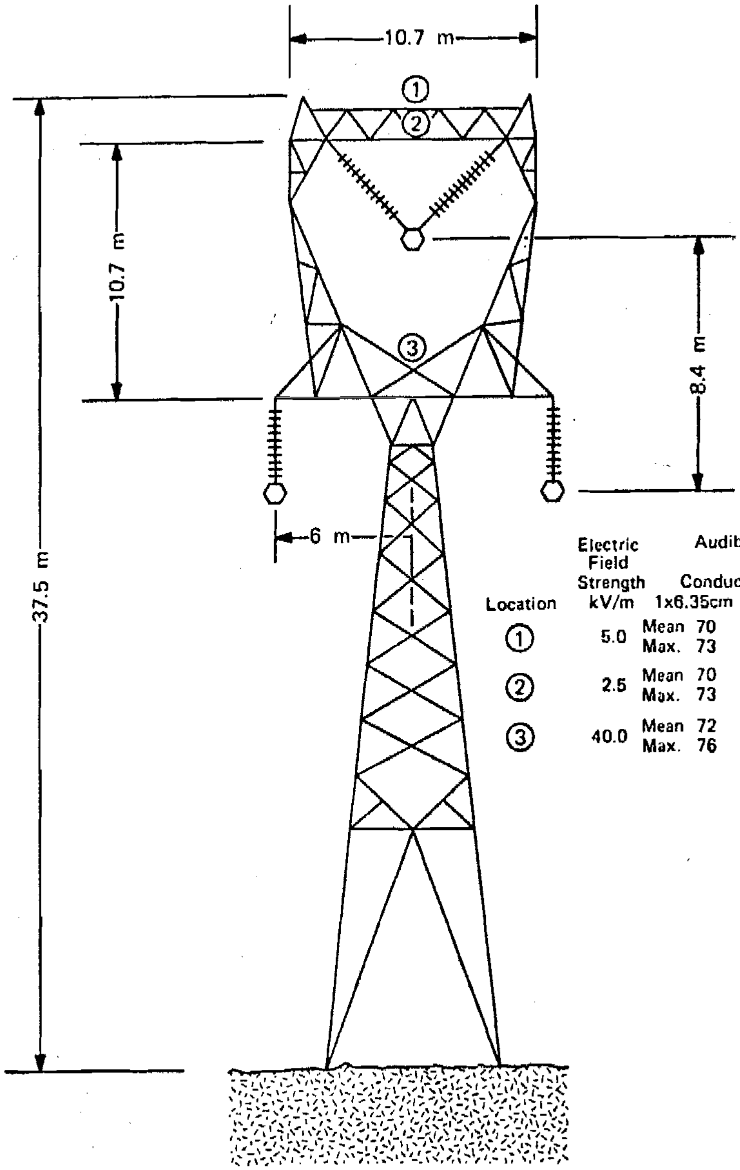
	500 kV a.c.		± 400 kV d.c.	
	Forested*	Non-Forested+	Forested**	Non-Forested++
Total Length of Lines Patrolled (km)	2024	1552	103	323
Number of Nests:				
Hawks	5	41	6	4
Ravens	0	35	1	
Golden Eagle	0	0	0	1
Unknown	0	56		1
Total Nests	5	132	7	6

* Lines in this category are located primarily in central and western Oregon and Washington and in Idaho in coniferous forest, vegetation types.

\+ Lines in this category are located primarily in eastern Oregon and Washington in shrub/grass and grass vegetation types.

** This category consists primarily of Western juniper (Juniperus occidentalis) vegetation type.

++ This category consists primarily of sagebrush (Artemisia spp.) grass and cropland.



Location	Electric Field Strength kV/m		Audible Noise During Rain dB(A) Conductor Configuration 1x6.35cm	2x4.07cm	3x3.31cm
①	5.0	Mean	70	62	54
		Max.	73	66	57
②	2.5	Mean	70	62	54
		Max.	73	66	57
③	40.0	Mean	72	65	56
		Max.	76	68	60

Figure 10 - Measured electric field strength and calculated audible noise for locations within a typical B.P.A. 500 kV a-c transmission line tower where raptors and other birds are known to perch and nest.

On one line that does have the single conductor design for its entire length (Vantage-Raver) a total of 13 nests were counted this spring. Apparently birds are not completely avoiding such lines because of their high AN characteristics.

It should be pointed out, however, that most of the nests on the Vantage-Raver 500-kV line are located east of the Cascade Mountains in a relatively dry climate. From March through May the mean precipitation is 51 mm and it is only 25 mm to 51 mm from June through August (Highsmith and Bard 1973:49). In this area precipitation and, therefore, the highest AN levels would occur only infrequently during the nesting season. The possible effects of AN of 76 dB(A) or more occurring for long periods of time on adult and young birds nesting in towers has yet to be determined. Woolf et al. (1976) reported that auditory stimulation of Japanese Quail eggs affected the developing embryo. It was found that 37 msec. bursts of sound of .0.1-8 kHz with a sound pressure level of 80 dB applied for two hours accelerated the time of hatching of the eggs by as much as 10 percent.

CONCLUSIONS

1. Transmission line audible noise (AN), produced by corona primarily from EHV lines, is one of many factors which contribute to the unique characteristics of a transmission line right-of-way. Any field study of the effects of transmisssion line AN on wildlife should acknowledge the possible synergistic actions of construction and maintenance activities, and effects due to electric and magnetic fields. To properly evaluate the potential impact of AN on wildlife requires a basic understanding of the technical aspects of AN.

2. The effect of transmission line AN on people is an environmental issue. Annoyance including possible interference with sleep is one of the most serious consequences of AN on people. When relating the human situation to wildlife several distinctions should be made. For wildlife, it is important to consider the maximum AN which occurs on the right-of-way. Differences in hearing abilities between man and wildlife should also be considered. With wildlife the effects of AN may not be entirely negative. It is possible that AN from transmission lines is a source of locational information for some species.

3. Relatively few studies have been conducted to determine the effects of transmission lines on wildlife. Of those which have been done, still fewer have addressed the possible effects of AN or other electrical parameters. In studies conducted on Bonneville Power Administration transmission line rights-of-way both positive and negative effects of the right-of-way environment have been identified. The nature and magnitude of these effects has varied among species and taxonomic groups. Although we do not discount the possible effects of AN or electric fields, we believe that ecological effects observed to date can largely be explained by physical changes in habitat due to construction and maintenance activities.

4. The effects of AN on even the most sensitive wildlife species may be difficult to detect in field studies due to marked temporal and spatial variation in wildlife populations. A possible exception is the reindeer, the behavior of which is reportedly affected by transmission line AN (Villmo 1972). The possibility of sampling bias due to the effects of AN on observers, and the fact that highest AN levels occur during foul weather, a time when wildife behavior is not well understood and when most wildlife observational techniques are severly impaired add to the difficulties of identifying the effects of AN on wildlife.

5. Increased public awareness of environmental pollutants such as transmission line AN has served to promote transmission line designs that minimize the production of AN. We would expect this trend to continue so that AN from newer EHV and UHV lines will be less than that produced by some of the first EHV lines constructed.

RECOMMENDATIONS

Although a growing number of studies are being conducted to determine the effects of transmission lines on wildlife, few such studies acknowledge the unique characteristics of the transmission line environment which distinguish it from other rights-of-way. We recommend that persons conducting such studies familiarize themselves with the technical characteristics of transmission lines. Most biologists have little or no training which is applicable to the highly specialized subject fields which are concerned with the theory and operation of EHV and UHV (ultra-high-voltage) transmission lines. We have found it necessary and extremely helpful to consult with a number of persons who have the necessary training to assist in designing and implementing studies which consider the electrical parameters of transmission lines. At the minimum we believe that reports of biological studies done on transmission line rights-of-way should provide sufficient information to describe the total right-of-way environment. Included should be such information as the number and voltage of lines present, the range of operating voltage during the study, the design of the line(s) including the size and number of subconductors, and the minimum conductor to ground clearances. Measurements of AN or at least subjective judgements of the levels encountered during the study should also be included. Other useful information would include the dates when the line was constructed and energized, the use made of access roads, and the kind of vegetation management activities utilized including information on the use of herbicides on the right-of-way.

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OCEAN NOISE AND THE BEHAVIOR OF MARINE ANIMALS: RELATIONSHIPS AND IMPLICATIONS

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INTRODUCTION

There is general agreement among biologists that the acoustical sense of aquatic animals probably constitutes their most important distance receptor-system. This is particularly true among members of two vertebrate lines, the fishes and the marine mammals, whose acoustical activities have been investigated at an ever-increasing rate of sophistication during recent years. A major conclusion drawn from these varied studies - inclusive of those using psychophysical, physiological and ethological methodologies - is that the acoustical system can, and does, provide its owner appropriate information, readily and rapidly, on a variety of functions relative to food, competitors, potential mates and predators.

Concomitant with the increasing sophistication of problem-queries, experimental designs and available instrumentation, there is a growing awareness that ambient noise, itself, can no longer be ignored in underwater bioacoustics. Not only is it probable that such noise actually affects, at least temporarily, the hearing abilities of the animals concerned, it may also act to inhibit sound production as well. Such a reduction in acoustic transmission and/or its reception can, of course, adversely affect the reproductive potential or even the survival of any given species or population that is dependent on such a sensory process. Additionally, evidence is beginning to show up which indicates that excessive noise can also have other more direct, deleterious consequences on marine biological systems (see below). This problem-area will become more widely recognized as more is