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Woodpecker Damage to Wooden Utility Poles.

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WOODPECKER DAMAGE TO WOODEN UTILITY POLES

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ABSTRACT

Research aimed at preventing woodpecker damage to wooden utility poles was conducted in Louisiana and Texas over a 7-year period.

Woodpecker damage to wooden poles occurs in most of the southwestern, southern, southeastern, and northeastern states; the Pileated (*Dryocopos pileatus*), Red-headed (*Melanerpes erythrocephalus*), Ladder-backed (*Dendrocopos scalaris*), and Golden-fronted Woodpeckers (*Centurus aurifrons*) are the species most commonly causing damage. Their work consists of three main types: check enlargements due possibly to food-searching activities, test probes with no known function but seemingly exploratory, and excavation of large cavities for roosting and nesting. These cavities sometimes are 18 to 24 inches deep with only a shell of the pole remaining. The current preventive, hardware cloth wrapped from the top to within 10 to 12 feet of the ground, is expensive, and its use negates the insulating properties of the wood poles.

Aviary tests were of little value but several conclusions were derived from field experiments. Birds are initially attracted to ring shakes in creosoted poles but poles without shakes were damaged also, although less extensively. Separations between the growth rings are probably induced by the treating process. Natural hardness in creosoted southern pine fence posts was not sufficient to deter attack

by Ladder-backed and Golden-fronted Woodpeckers. Coated fence posts and noncoated controls did not have sufficient damage to evaluate the coatings. However, one of the same coatings (small rocks embedded in an epoxy) was completely effective on laminated pole sections, and a proprietary wrap was equally effective on round poles. Sections of creosoted white pine (*Pinus strobus* L.) bolted to poles at strategic heights for decoys were readily attacked by woodpeckers, but the poles were also damaged. Chemicals seem to offer little promise as deterrents.

Woodpecker damage to poles can be repaired, but unless protective measures are taken, new damage occurs. Leaving existing cavities for birds to use does not prevent new damage.

The size of pole, severity of damage, and distance from ground line to damaged portion of the pole are measurable variables affecting pole strength. Specific gravity, presence of knots, method of conditioning, stress concentrations at points of damage, and natural variation in wood are some of the factors complicating a model derived to predict the amount of strength retained in damaged poles as determined by calculations of reductions of moments of inertia.

Decay does not seem to be associated with woodpecker cavities, although considerable rainfall enters the cavities.

Hardware cloth provides good protection and its durability is proven. It will probably continue to be used where preventive measures are deemed appropriate.

WOODPECKER DAMAGE TO WOODEN UTILITY POLES

INTRODUCTION

Wood poles are important to the forest industry because they bring a good economic return and because they provide a market for thinnings before stands attain sawlog size. The removal of some pole-size timber accelerates the growth of the remaining trees while providing the forester with an income prior to the end of rotation. Also, there is no further expense of conversion into secondary products. The peeled, round, tapered pole is ideal for use in the communication and electric utility industry because it is strong and is a poor conductor of electricity. Wooden poles are also cheaper than concrete or steel substitutes.

There are approximately 125 million utility poles in service in the United States. Every year between 2 and 3 million are added. Gill and Phelps (1971) reported that about 50 percent of the 5.3 million poles treated in 1970 were utility poles and 20 percent were construction poles; the remaining 30 percent were not specified as to use. They also stated that nearly 93 percent of the poles were pressure-treated. Forty-one percent of all poles were treated with creosote and creosote solutions, and 48 percent with petroleum-pentachlorophenol. The remainder were processed primarily with salts treatments, many of which involve patented processes. Three-fourths of all poles were treated in the south-central and southeastern states. Nationally, 88 percent of all pressure-treated poles were southern pine.

Poles are not graded as is lumber, but in regards to defects they must conform to certain standards usually applied at time of harvest. Poles are placed in certain classes on the basis of fiber stress of 8,000 p.s.i. and certain minimum circumferences at the top and 6 feet from the butt. Depending on the class, poles must be able to withstand a given load applied laterally at the top. For instance, a 45-foot class 5 southern pine pole has minimum circumferences of 19 inches at the top and 32.5 inches at 6 feet from the butt; a lateral load of 1,900 pounds is considered the breaking load (American Standards Association 1963). Poles are categorized as transmission or distribution mainly on the basis of their use. However, transmission poles are generally from the larger sizes.

The supplier burn-brands each pole to inform the user of certain pertinent facts concerning the product. The brand usually contains the supplier's name, plant designation, year of treatment, kind of timber, type of preservative used, pole class, and length (Figure 1). Many utility companies subscribe to an inspection service, which ensures that the poles conform to specifications. But even if all standards are followed, and the proper load assigned to each pole, the calculations can soon be negated by woodpeckers removing a large portion of the cross-sectional area of a pole soon after it is placed in service.

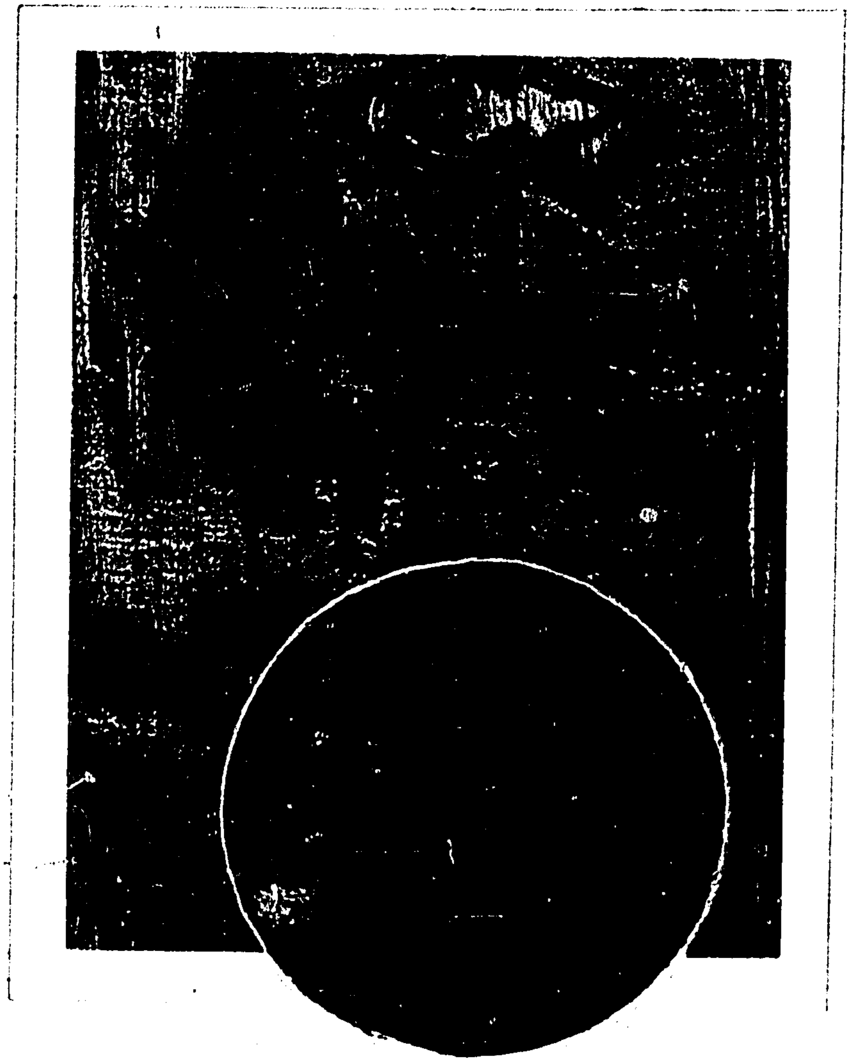


Figure 1. Pole brand showing supplier (Colfax Creosoting Co.), kind of timber, preservative, and amount (southern pine, creosote, 8 pounds per cubic foot), plant designation and date of treatment (Pineville, La., November 1963), and pole size (class 5, 40-foot).

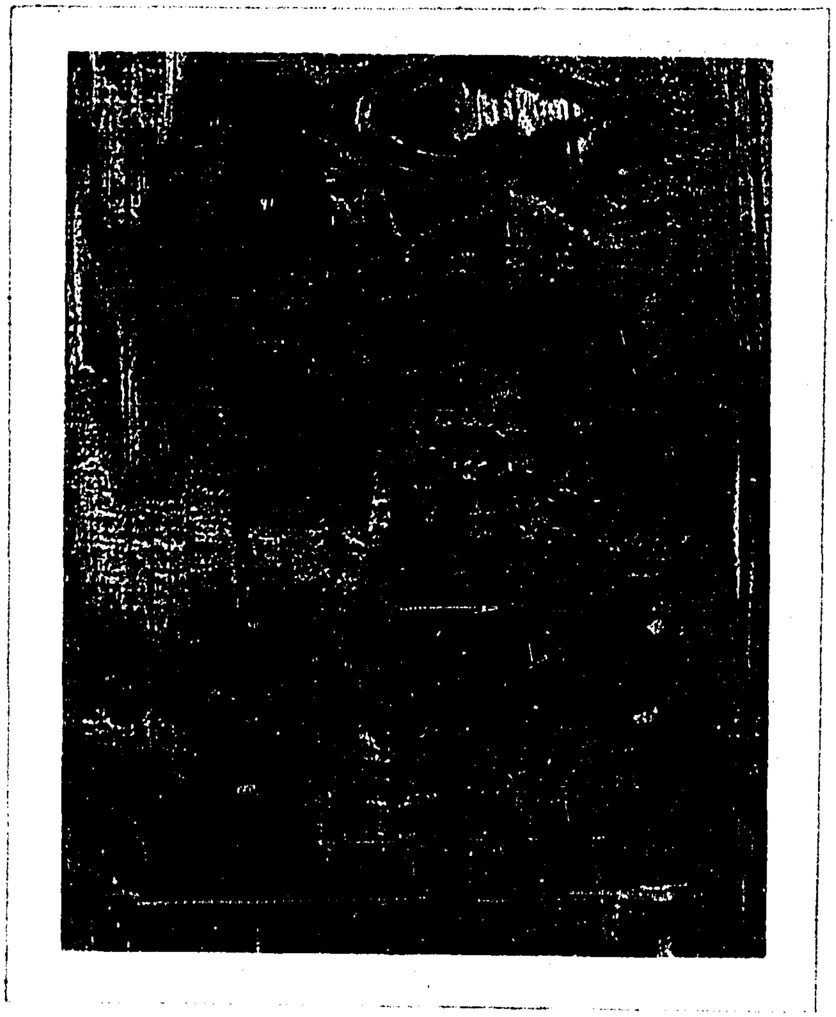


Figure 1. Pole brand showing supplier (Colfax Creosoting Co.), kind of timber, preservative, and amount (southern pine, creosote, 8 pounds per cubic foot), plant designation and date of treatment (Pineville, La., November 1963), and pole size (class 5, 40-foot).

Geographical Area of Damage

Woodpecker damage to wooden poles occurs throughout the Holarctic region (Turcek 1960). In Japan, the U.S.A., Sweden, and Finland the damage is so severe that control measures have been sought. Dennis (1964) described the geographical area of damage in the United States as being primarily the eastern part of the country. He added that incidence of attack may be local, depending on species of bird doing the damage. Generally, the Gulf South region appears to be the major area of attack.

Species of Woodpeckers Causing Damage

Of the 179 species of true woodpeckers (Picinae) in the world (Mayr and Amadon 1951), 22 species representing nine genera occur in North America (American Ornithologists' Union 1957). Dennis (1964) found that five genera were mainly responsible for damage to utility poles: *Melanerpes*, *Centurus*, *Dryocopus*, *Colaptes*, and *Dendrocopos*. And although some representatives of these genera occur in the southern hemisphere, damage seems to be restricted to the northern hemisphere. Dennis listed seven species that damage poles in North America: the Ladder-backed Woodpecker (*Dendrocopos scalaris*)[1/], Golden-fronted Woodpecker (*Centurus aurifrons*), Red-headed Woodpecker (*Melanerpes erythrocephalus*), Acorn Woodpecker (*Melanerpes formicivorus*), Pileated Woodpecker (*Dryocopus pileatus*), and Red- and Yellow-shafted Flickers (*Colaptes cafer* and *C. auratus*). Pileated and Red-headed Woodpeckers cause almost all the damage in the southern, southeastern, and eastern states.

[1/] Nomenclature from A.O.U. Check-list of North American Birds, 1957.

Red-headed Woodpeckers damage not only the small distribution poles but also poles of the large transmission sizes. Pileateds, because they are so much larger, are able to use only the transmission poles for roost and nest cavities. Pileateds prefer to excavate that portion of the pole from about midway up to the top quarter, while Red-heads use the uppermost portions. However, there are many instances where Pileateds start a cavity about half way up a pole and for some reason do not complete it; Red-heads readily move in and complete the cavity although it is not at the height normally selected. Occasionally Pileateds and Red-heads will nest in the same pole, but neither species will tolerate another pair of its own kind that close.

The two species of the Southwest, the Ladder-backed and Golden-fronted, not only damage poles but also excavate cavities in fence posts and crossarms (Figure 2). Cavities in crossarms are near the end, always on the bottom, and extend back toward the pole (Dennis 1967). These cavities cause some arms to fail at the excavation site.

Damage by the Acorn Woodpecker and by flickers is minimal compared to that previously mentioned for other species and will not be discussed in this paper.

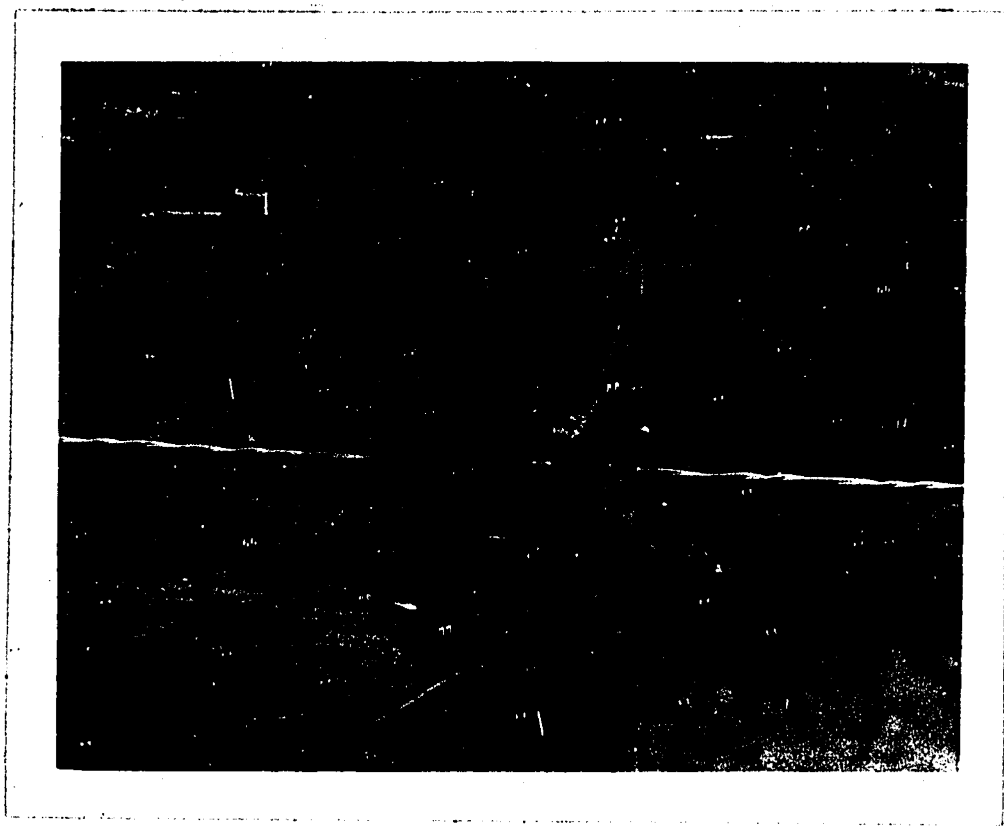


Figure 2. Nest cavity excavated in fence post by Ladder-backed Woodpecker. (Laguna Atascosa National Wildlife Refuge, Cameron County, Texas, 1970.)

Kinds of Damage

There are essentially three types of woodpecker damage, separable by kind of excavation and function. The least kind of damage is the enlargement of checks, supposedly a food-searching activity since many insects can be found in these crevices. Check enlargements usually are less than an inch deep but may extend for several inches along a check.

Of more concern to utility companies are the numerous holes that extend inward several inches toward the core of the pole but with no upward or downward excavation. These holes are seemingly functionless, almost as if the birds are testing or exploring the pole prior to further excavating. Such test probes when excavated by Red-heads are somewhat spherical (Figure 3), while those excavated by Pileateds are more angular (Figure 4). In either case, the openings are 3 to 4 inches in diameter and extend inward for various distances. Since the preservative is concentrated in the outer portion of a pole, these holes frequently penetrate into relatively untreated wood. Often there are several holes of this type in a pole. If they were excavated during the period when the birds were coming into breeding condition, the holes might seem to be the result of incomplete, or abortive nesting attempts--a trait found in some species of birds. However, test probes are made throughout the year.

Of most concern are the large cavities excavated for roost or nest sites (Figure 5). Openings to these are oval, 3 to 5 inches in diameter, and extend well past the core of the pole. Often only an outer shell of wood 1 to 2 inches thick remains. Cavities always extend downward from the entrance hole, that is, the opening is at the top of

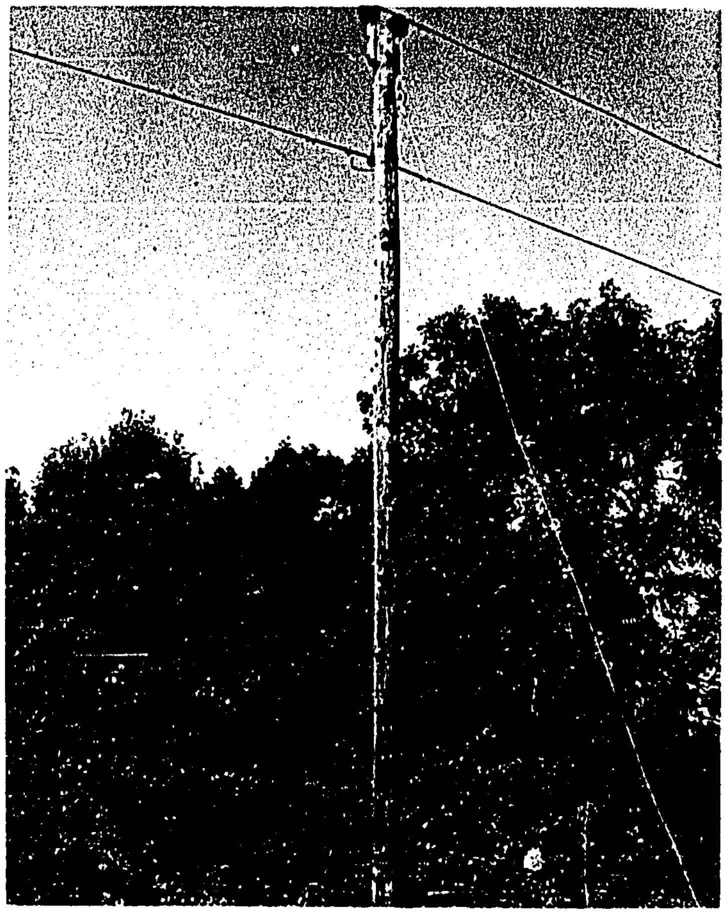


Figure 3. Test probes by Red-headed Woodpeckers are usually spherical and extend inward only, not downward. Some poles have several such probes. (Saline Wildlife Management Area, LaSalle Parish, Louisiana, 1967.)

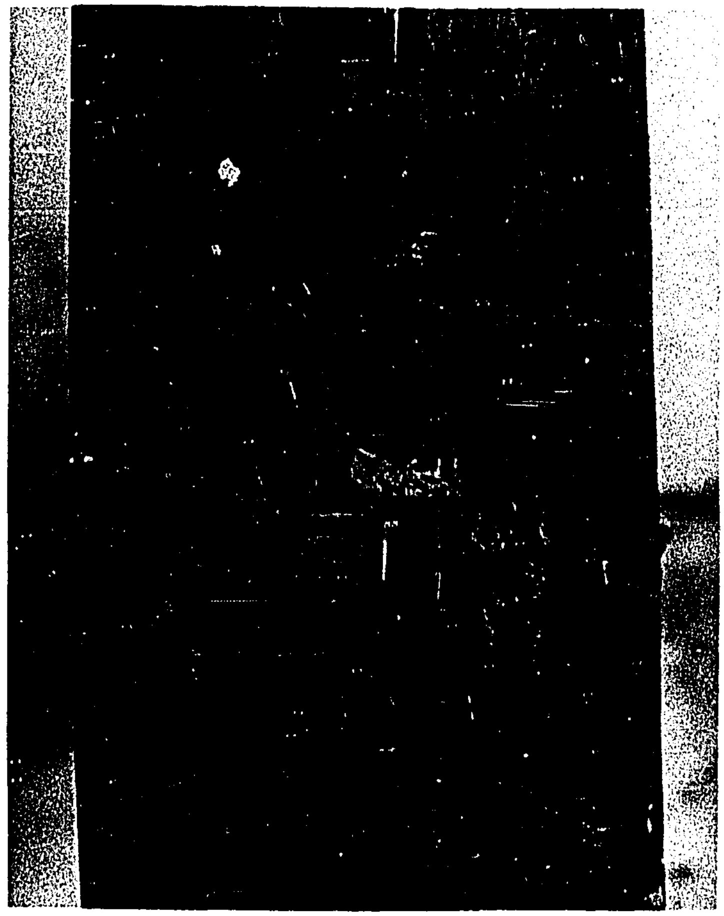


Figure 4. Test probes by Pileateds extend inward only, are angular in shape, and are often in burst checks. (Saline Wildlife Management Area, LaSalle Parish, Louisiana, 1966.)

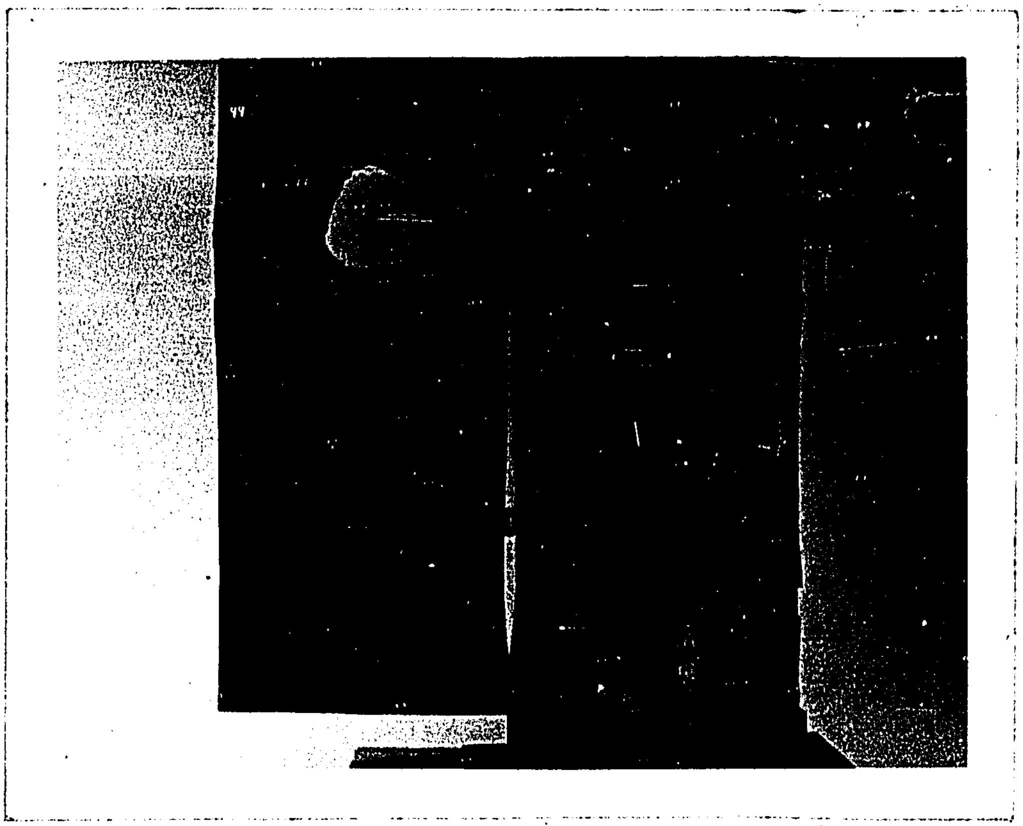


Figure 5. Section of pole showing nest cavity of Pileated Woodpecker. (Scale is in inches.)

the cavity. When completed, these excavations are a foot or more in depth, and when used in succeeding years, which is not uncommon, they may be as much as 2 feet deep.

Reasons for Attack

Why woodpeckers choose poles instead of trees for their activity is not fully understood. Many of the reasons advocated have been discounted with a discourse on why they are not acceptable rather than why they are. Turcek (1960) was one of the first to summarize the theories up to that time. He discounted the idea that the activity was due to a shortage of suitable trees for roosting and nesting as suggested by some researchers. And as for the hypothesis advocated by Nakajima and Shimizu (1956) that woodpeckers peck the poles to prevent abnormal growth of their bills, Turcek stated it was "biologically quite untenable." After discounting these considerations, along with the suggestion that the acoustical stimulus of buzzing or humming in poles acts as an attractant, Turcek concluded that the damage to poles in Czechoslovakia was related to the preparation of winter roosting holes. However, his reasoning follows a functional rather than a causal approach.

Dennis (1964) examined five broad headings as reasons for attack: (1) resonance of the poles, which would provide an acoustical stimulation; (2) changes in habitat, resulting in an increase in woodpecker density; (3) territorial behavior, resulting in competition for new poles placed within the birds' domain; (4) internal voids or outward appearances of poles, which cause birds to believe the poles were

decaying trees; and (5) food searching. Dennis' conclusion was that a utility pole may be selected rather than a dead tree for a variety of reasons; namely, the pole's strategic location in the cleared right-of-way makes it advantageous in territorial and courtship behavior; the pole is the right height and dimension to be attractive to the bird as a site for roost or nest cavities; and finally, but not to be emphasized, a shortage of suitable natural sites. Whatever the reasons for attack, the fact remains that utility companies have found woodpeckers to be a serious economic problem for the last 25 or 30 years.

Financial Aspects of Woodpecker Damage

An estimate of the annual cost of woodpecker damage by competent appraisers is not available, but it is easily in the millions of dollars, especially when expensive preventive measures are included. Typical prices for poles in central Louisiana at the job site are shown in Table 1. While there are variations throughout the country, the table can be used as a guide. To the price of a pole can be added the expense of setting ($30 to $50) and the cost of wrapping ($30 to $50) the pole with hardware cloth, which is the current preventive measure used (Figure 6). If a transmission line with 55-foot class 2 poles is used in the estimate, each pole in the ground with no attachments represents an investment of approximately $185 to $210. Transmission lines are frequently of the H-frame type where two poles are set at each span--and there may be eight to 10 spans per mile. A total of $4,000 is estimated then as the cost of poles per mile, with $600 to

Table 1. Cost of creosoted southern pine poles, August 1971[1/]

Length	Class 1	2	3	4	5	6
Feet	Dollars					
30			30.70	25.20	23.60	20.70
35			41.90	37.70	33.90	27.30
40			53.70	47.60	41.80	35.80
45	89.50	71.40	64.20	56.40	49.60	44.70
50	100.40	87.80	76.10	67.50	59.00	
55	121.00	107.10	96.30	81.00		
60	145.20	134.70	115.60	100.70		
65	186.50	161.90	142.70	118.00		
70	220.00	189.90	170.90			
75	260.10	222.20				

[1/]Minimum cost at job site; 10 pounds of preservative per cubic foot.

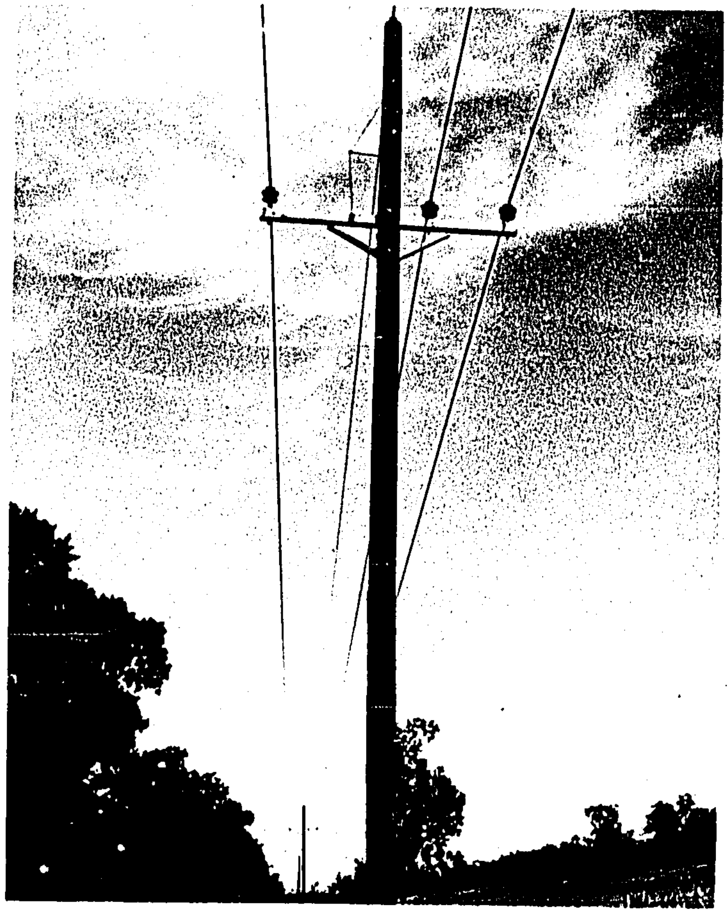


Figure 6. Eight strips of 19 gauge, 2 x 2 hardware cloth were used to wrap this pole. Although Pileated Woodpeckers have torn through, hardware cloth offers the best practical protection available. (Saline Wildlife Management Area, LaSalle Parish, Louisiana, 1970.)

$1,000 per mile attributable to woodpecker damage prevention. The cost of changing-out a damaged pole can easily be several times the initial cost because of labor and inaccessibility of many transmission lines.

Dennis (1964) referred to correspondence with a private utility company that reported a single year's expense of $191,000 attributable to woodpeckers. I have made recent calculations for the 10 Gulf South companies supporting research at the Southern Forest Experiment Station by using one company's figures and prorating them on the miles of transmission lines for the others. If one assumes that the companies are comparable as to the amount of woodpecker damage on their lines, and replacement, repair and maintenance costs are about equal, then a figure of $743,242 per year is the cost attributable to woodpeckers for these 10 companies. In the Directory of Electric Utilities (1971) there are 244 investor-owned utilities and 932 rural cooperatives listed in the United States. If only a small percentage of these companies have a woodpecker problem, it is evident that a total cost of several million dollars per year is a reasonable estimate of damage by woodpeckers to wooden utility poles.

Objectives of the Study

The primary objective of this study was to develop effective and economical means of protecting wooden utility poles from woodpecker damage. This necessitated formulating several other objectives, namely: (1) to define the problem, (2) to determine species of woodpeckers causing the damage, (3) to determine why woodpeckers damage poles, and (4) to evaluate how serious woodpecker damage is to poles.

REVIEW OF LITERATURE

Sennett (1878) apparently gave the earliest account of woodpecker damage to wooden poles when he reported finding damage by Ladder-backed and Golden-fronted Woodpeckers to the square government telegraph poles of the Southwest. He believed the numerous holes (up to 10 in one pole) were excavated for nests, but in a later publication (Sennett 1879), he stated that the holes were made by birds searching for a large species of wood-boring insect. However, poles were so inexpensive or the damage so infrequent that there was little economic concern for several years.

By 1910 the problem had become one of increased interest. McAtee (1911), in a detailed study of this and other problems involving woodpeckers, reported that there were six species of small woodpeckers causing damage to poles. McAtee was hopeful that one of the preservative treatments would solve the problem, but he suggested that nest boxes might reduce the damage. There was no mention of damage by Pileateds.

Weiss (1911) published some data on the frequency of damage and also on the reduction of strength caused by woodpeckers. In 1906 he checked 268 telephone poles in Louisiana and found 110, or 41 percent, had been attacked. On two lines in southern Indiana he found 21 percent and 41 percent of the poles damaged. Weiss listed some control methods that had been attempted: shooting, hanging the birds by placing a horse hair noose at the entrance hole, and placing pebbles in the cavities.

Of greater interest is Weiss' account of the strength loss in poles. He measured the taper of 250 30-foot northern white-cedar poles, and by assuming them to respond as cantilevers when loaded at one end, calculated the amount of wood that could be removed from the poles by woodpeckers without causing a serious decrease in strength. For instance, at 10 feet from the ground a shell of only 2 inches was needed for the pole to be approximately as strong as when it was solid. Weiss also reported on tests made by the American Telephone and Telegraph Company in Ohio in 1908. A rope and dynamometer were attached to the tops of poles damaged by woodpeckers, and in nine cases out of 12 when a load was applied the poles broke at the groundline rather than at the points of woodpecker damage. The last sentence in Weiss' report undoubtedly influenced the attitude toward woodpeckers for several years. He wrote:

> "It appears, therefore, that the attack of poles by these birds is not as serious as one would be prone to believe and, taking into account the great good they do in eating insects, the destruction of our feathered friends can by no means be justified by the injury they do to pole-line construction."

Beal (1911), on the basis of an examination of 3,453 stomachs, found that ants and beetles were the two most important items in the diet of woodpeckers. Forbush (1913) added further to the favorable attitude toward woodpeckers by emphasizing their role in destroying forest insects. In 1918 the Migratory Bird Treaty Act was passed, which placed all woodpeckers in the United States on the protected list.

For the next several years, there seems to have been little concern regarding the woodpecker problem. Prior to the mid-1940's populations of Pileateds, and possibly Red-heads were low, probably due in large part to the drastic timber harvesting practices in vogue shortly after the turn of the century. Habitat suitable for woodpeckers was limited until the second-growth timber attained a sufficient size. Also, about that time utility companies were extending lines into rural areas where woodpecker populations were highest.

In the 1950's there were two significant events in the woodpecker-utility pole problem. First, the results of using hardware cloth (galvanized steel mesh) as a pole protectant were published (Rush 1953), and second, a concerted research effort was begun at Pennsylvania State University to find methods of preventing damage.

Apparently hardware cloth was first used in 1948 by the Louisiana Power and Light Company (Lancaster 1962). The first material tried was 21 gauge, 2 x 2 mesh in a 48-inch width. This mesh size has two openings per inch, which means there is one-half inch from the center of one wire to the next center. When it was evident that woodpeckers could tear through that material, the company changed to a larger 19-gauge wire, which gave 95 percent or better protection (Figure 7). The poles were wrapped to within about 12 feet of the ground line since birds very seldom attack poles that close to the ground. The procedure today is essentially the same, except that 3 feet seems to be the preferred width of the hardware cloth, and most of the poles are wrapped while on the ground prior to construction of the lines. Two of the major objections, expense and electrical conductivity, have not been overcome.

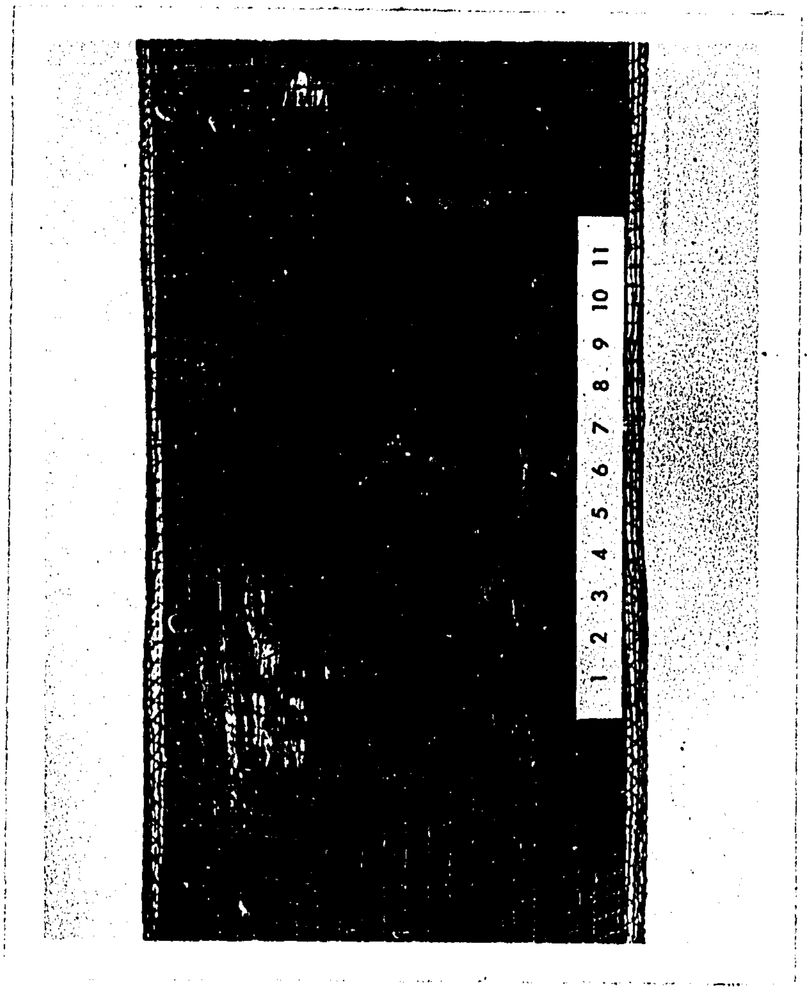


Figure 7. Pileated Woodpeckers occasionally get through 19 gauge, 2 x 2 hardware cloth by "fatiguing" the wire. (Scale in inches.)

The research at Pennsylvania State University was started in 1955 in cooperation with several utility companies in Pennsylvania that were experiencing woodpecker damage. The effort was directed only toward the Pileated, since that was the species causing the trouble. The research consisted of two phases: a study of woodpecker activity along utility lines to determine life history and relationship to damage, and the testing of numerous mechanical and chemical repellents (Jorgensen et al. 1957). The researchers believed the most important feature of their observations under the first phase was that damage to poles was serious only in certain months, the 6-month period from October through March. Consequently, a short-term repellent might have application. Another finding was that there was no correlation between type and amount of damage and local occurrence of open fields or forests of various age classes. But it seemed to the researchers that damage was less where the most mature timber existed, which was assumed to be the best environment for the birds.

Jorgensen et al. (1957) also found that sections of utility poles painted white, red, green, and yellow were damaged more than control sections. Also, aluminum paint was not repelling. Their tests also showed that several coverings effectively prevented the birds from getting at the wood: galvanized and aluminum sheet metal, heavy wire mesh, and fiberglass tubes were not penetrated. None of those coverings were deemed practical under maintenance conditions in use at that time. Jorgensen and his coworkers also tested 75 chemical compounds and commercial repellent materials in an aviary; eight were capable of repelling a captive Pileated Woodpecker. However, field tests subsequently

revealed none of those eight was effective. In further tests at Pennsylvania State University researchers evaluated about 45 other chemicals and compounds without success (Unpublished, Project 1256, Progress Reports 7 and 8, no. date). Hawk silhouettes, plastic spinners, and recorded distress calls played back were also tested without success. The work at Pennsylvania State University was apparently terminated in 1962 after a period of about 7 years.

In the late 1950's and early 1960's other results with chemical repellents indicated that a solution to the problem might be available. One of the proprietary repellents tested at Pennsylvania State University, Roost-No-More, was reported to be completely effective after 2 years in the field (Anonmyous 1958). Also, Dennis (1963a; 1963b) presented accounts of the success of another proprietary product, Koppers Woodpecker Repellent. Roost-No-More could be sprayed, but Koppers Repellent contained a heavy grase base and was applied with a brush. Dennis (unpublished office report, 1965) later stated that both materials were relatively short-lived; they were effective as long as they were tacky or gave off a pungent odor.

Some comments by Koersveld (1957) regarding chemical repellents are pertinent. Most repellents are designed to act on the senses of taste or small, based unfortunately on subjective human judgements of what is objectionable. The repelling action is often caused by volatile ingredients, which are effective for a limited time. Also, birds seem to become habituated to odors, but not to repellents having a pharmacological action, such as emetics.

In 1965 five Gulf South utility companies, which were not completely satisfied with preventives in use at that time, entered into an agreement with the U. S. Forest Service in an effort to find a more acceptable solution. Before the research was terminated in 1972, a forestry company and five other utility companies had participated for varying lengths of time. This report includes information gained from that research.

Life History, Behavior, and Morphology of Selected Woodpeckers

This section is not intended to be all inclusive, but is a review of pertinent facts about woodpeckers to give the reader a better understanding of the research problem. Also included are popular and scientific accounts such as those by Bent (1939), Hoyt (1957), Kilham (1959), Farb (1962), and Smith (1968). The species selected for discussion are the Pileated, Red-headed, Ladder-backed, and Golden-fronted Woodpeckers. The latter two are included since they were efficacious for certain preliminary experiments in this research.

Territory size of woodpeckers along a utility line would likely be an important factor in estimating the amount of damage incurred, for the larger their territory the less their density. It is unreasonable to attempt a categorization of the type of territory maintained by Pileated Woodpeckers following Nice's (1941) functional definitions. To what extent, if at all, Pileateds are territorial is not clear. Hoyt (1957) believed there must be fights over territorial boundaries but had no records and knew of no one who had witnessed such incidents.

Kilham (1959) noted conflict along the boundaries between two pairs of Pileateds in Florida, but did not indicate the size of the defended areas. Kilham (1958) found wintering territories where Red-heads stored acorns to be small in size; 12 birds maintained territories in a 4-acre area.

With the exception of the Red-headed Woodpecker, all the species are sexually dimorphic. All are probably nonmigratory but some make seasonal shifts in their ranges. Calling, drumming, and displaying occur in courtship behavior. Several false starts before a nest cavity is completed seems to be common to all. Both sexes of all four species participate in nest construction, incubation, and care of young. Adult and young Pileateds remain together well past summer and can be observed feeding as a family group. However, young Red-heads are driven from the area of the nest soon after fledging. This is probably an adaptation permitting the adults to renest, which they do in the southern part of their range. Young Red-heads, until well after the nesting season, are easily recognized from a distance by the absence of red coloration on their heads. This is not the case in Pileateds, where the young soon resemble the adults in plumage and can even be sexed when a few days old by the extent of red on the forehead. (The red color on a male extends to the base of the bill, but on a female terminates at a point near the top of the head.)

Pileateds are primarily occupants of older deciduous forests, but they are quite adaptable to most wooded areas with the exception of pure pine stands. During much of the year Red-heads are found in habitats

varying from open fields containing a few trees to sparsely wooded areas. During the winter they often move to more heavily wooded areas and might occupy the same habitat as the Pileated. Such a seasonal shift is presumably related to the availability of food, since flying insects that the Red-head is capable of taking on the wing are not available in quantity during the winter months. Woodpeckers seem to be opportunists in feeding on whatever is available, but generally the amount of animal material in the diet exceeds vegetable matter.

Most of the damage to wood products in the South occurs shortly before and during the nesting season. Red-headed and Pileated Woodpeckers damage poles only, but the Ladder-backed and Golden-fronted damage poles, fence posts, crossarms, and sign posts. Excavations in fence posts and crossarms are used for nesting and roosting.

Since a repellent or treatment must have an effect on a target organ to be effective, certain morphological features of woodpeckers were studied in an attempt to find an avenue to affect the birds' sensory mechanism. Physiological and physical attributes were examined.

Woodpeckers have evolved numerous adaptations for their specialized way of life. Their legs are short and the toe arrangement on the feet is unique (zygodactyl), having two toes forward and two backward, which permits a double pincer grip (Figure 8). Bock and Miller (1959) have shown that this is a perching rather than a climbing foot. The claws, which are curved and sharp, enable a bird to cling to a wide range of textured surfaces. To facilitate propping on vertical surfaces, the middle two rectrices have become stiffer. Molting of the tail feathers

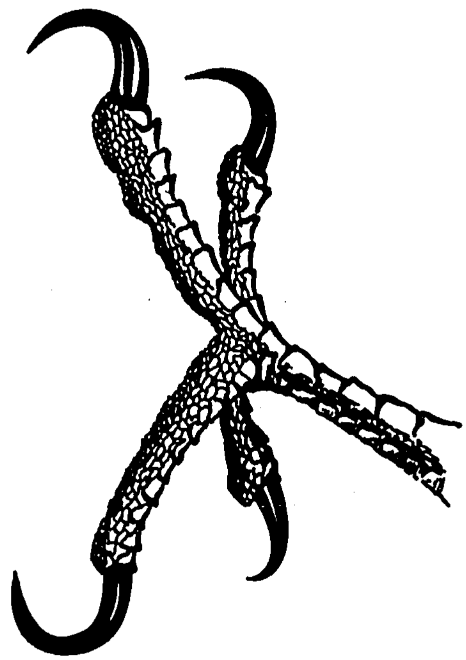


Figure 8. Zygodactyl arrangement of toes assists woodpeckers in clinging to vertical surfaces.

occurs in a sequence so that at no time are the birds without a sufficient number to provide their 3-point prop. The bill, which is used for shearing and prying, is hard, and sharp, and chisel-shaped with its vertical distance being greater than its width (Figure 9). The connection between the beak and skull is apparently not ossified, which permits the spongy, resilient tissue to absorb the shock from pecking (Beecher 1953).

Tongues of woodpeckers are hard and bonylike, with a barbed tip to facilitate impaling insects (Figure 10). A mucilagenous saliva produced in abundance causes smaller insects to adhere when the tongue is probed into galleries. The tongue is actually the terminal part of the hyoid apparatus (Figure 10), a system of strong, elastic tissue which divides in the back part of the mouth, passes on each side of the neck, rejoins over the skull, and is anchored in the right nostril. The arrangement permits extension of the tip several inches beyond the end of the beak; the tongue can also be bent and curved along its length.

The information on taste perception in birds is quite general. Portmann (1961) believed birds could distinguish the four primary tastes perceived by man, but to what extent he did not know. The taste ability seems to be poorly developed, probably because birds have relied more on eyesight to take their food. Also, taste receptors of birds, although similar in structure to those in mammals, do not occur in taste bud aggregations visible to the naked eye. And compared to mammals, taste buds in birds are very few in number and occur at the sides and base of the tongue, never at the tip. Furthermore, some species of birds tested seemed to be insensitive to bitter tastes.

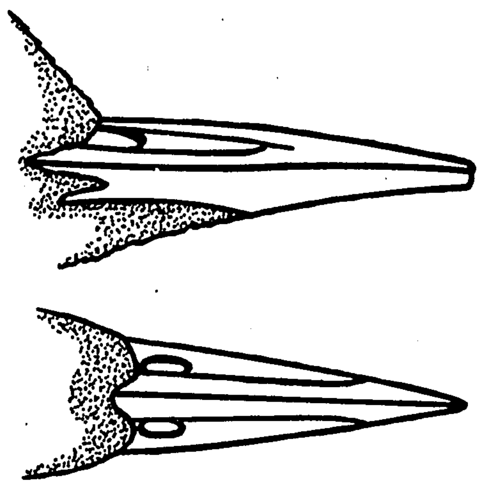


Figure 9. Side and top view of chisel-shaped beak of woodpeckers.

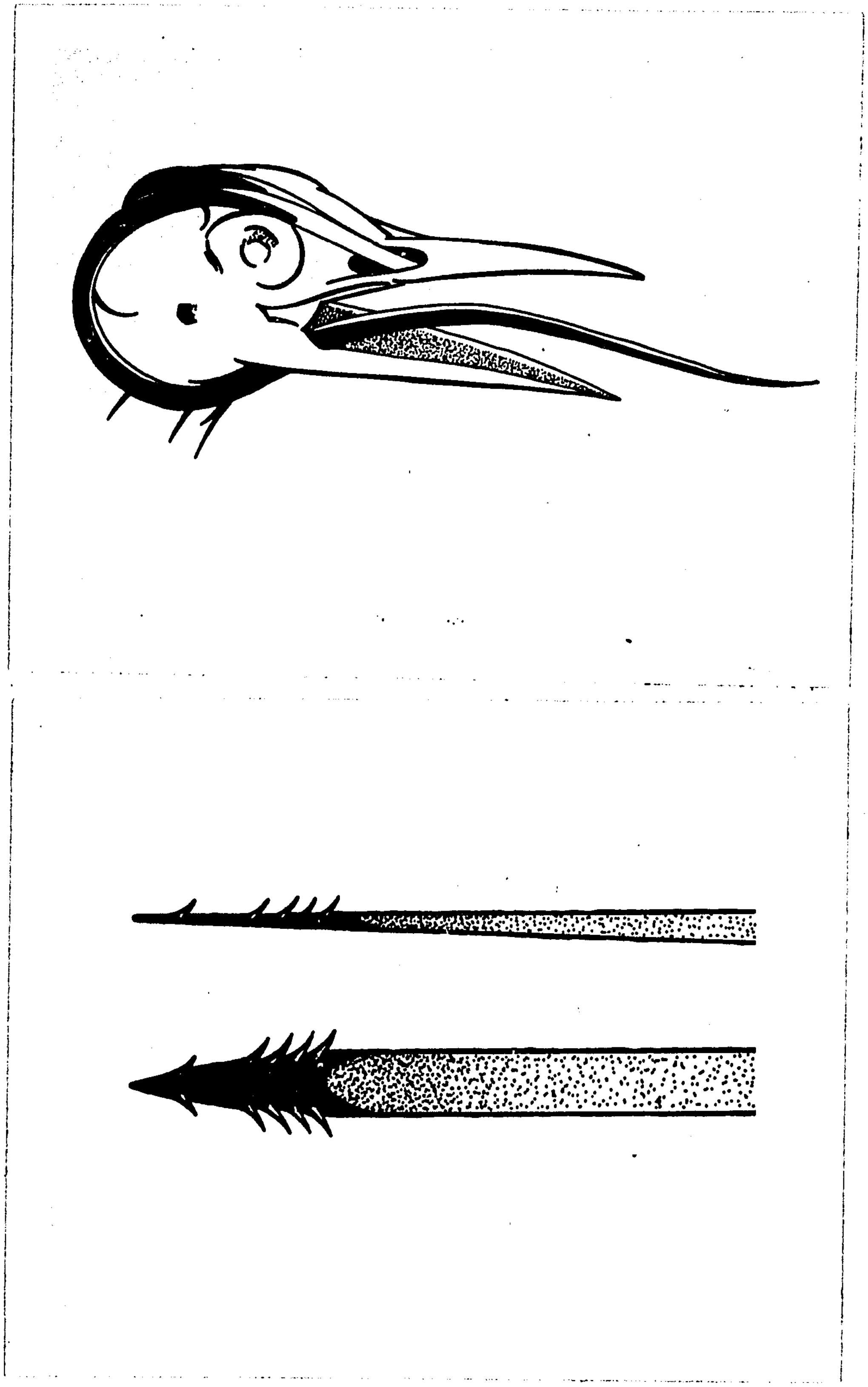


Figure 10. Hyoid apparatus and barbed tongue of woodpeckers. Top sketch shows arrangement of hyoid apparatus. Bottom sketch shows side and top view of barbed tongue.

Two observations on known bird repellents are noteworthy. First, the method by which, or reason that, a few chemicals act as repellents is not known. The taste of some of the repellents is reportedly not unpleasant to humans. Second, some of the material, coated seed for instance, is ingested before a repelling or avoiding reaction occurs. But woodpeckers probably do not ingest wood intentionally, although some might be swallowed incidental to pecking. Therefore, the task of finding a practical and successful taste-repellent chemical that will be effective against woodpeckers appears formidable.

The sense of smell, like taste, seems to be poorly developed in birds. This conclusion has been based on the observation that the olfactory lobes of the brain are small, and the intuitive knowledge of the futility for flying birds to follow scents in the air. Ground-dwelling birds, such as ducks and snipe, have better developed olfactory lobes and nerves than birds that spend less time on the ground. On the basis of morphology, Portmann (1961) expressed his disbelief that birds are completely anosmic (unable to detect odors). One popular account cited by Bent (1939, p. 182) attributed the strong formic acid smell of ant colonies as leading Pileated Woodpeckers to the exact location of the colonies within tree trunks. Since woodpeckers have evidently not been the object of intensive study, their olfactory capabilities are unknown. However, it appears that the possibility of using a woodpecker's sense of smell as a target for repellents is potentially unpromising.

Some ornithologists believe woodpeckers have the ability to hear moving insects within a tree or log after the insects are disturbed by the birds' tapping (Hoyt 1950). The characteristic feeding habit of a woodpecker is to move over the surface of a tree, tapping lightly, pausing after every few taps to turn its head sideways, and waiting a few seconds before tapping again. Contrary to some other ornithologists who believed the bird paused to look for enemies, Hoyt said it was listening for a response from the insects inside.

Pumphrey (1961a) stated that physiological and behavioral studies on hearing supported conclusions he had obtained from anatomical study; namely, that a bird can hear and respond to fluctuations 10 times as rapidly as can man; the band of frequencies to which a bird is sensitive probably lies within 200 and 10,000 cycles, with the exception of owls and parrots where it is higher; and the ability to determine the direction of a sound is comparable to man's. A young human before there is any aging in the ears can hear sounds, depending on intensity, from about 30 to 20,000 cycles per second; in older age the range is about 50 to 8,000 cycles per second (Guyton 1961, p. 690). It appears, therefore, that if a sound were found to be repelling to woodpeckers, it would also be in the audible range of (and unpleasant to) humans. Pumphrey also dispelled the idea that birds could hear far-away explosions; the birds actually responded to sound transmitted through the ground and perceived by sensory end organs, called corpuscles of Herbst, in the legs.

Pumphrey (1961b) indicated that some of the comparisons between avian and human eyes are misleading. For instance, it is believed that hawks, kites, and vultures are attracted to objects that would be invisible to humans from the same distance and that insect-eating birds can support themselves by taking insects that would be invisible to humans. Pumphrey stated that neither of these arguments is valid--if a human retained the power of accommodation he had when 2 years old, and could get as close to insects as a bird usually does, the human would have no trouble in seeing the insects; also, if a man's attention is accurately directed, he could see an antelope or its shadow and determine whether it is stationary or moving from a height of 10,000 feet. A man could see a moving herd of antelopes only as a group of moving, unidentifiable objects, and he could not adequately cover all the antelopes in about 40 square miles of territory as could a bird. Pumphrey summarized the evidence by stating that the acuity of birds is of the same order as that of men, but the rate of assimilation of detail is very much higher in birds, that is, vision in birds as a whole is no sharper but much faster than in man.

Although the sense of sight of woodpeckers has apparently not been studied in detail, the birds do not seem to possess any attributes that could be used as targets for repellents. Dr. Richard N. Jorgensen of the Pennsylvania State University (personal communication) thought the white markings on the tail and wings of Pileated Woodpeckers served as an alarm signal when a bird took flight. He noted that the birds did not call but seemed somehow to warn others of danger. Apparently Jorgensen was not able to duplicate the warning signal satisfactorily for field tests.

Ecology of Woodpeckers Nesting in Poles

The evidence that a population of woodpeckers along a utility line serves a beneficial function by reducing the number of forest insects is *a priori*. The importance of the function is likely to be overemphasized by ornithologists, while utility company engineers are more concerned with damage to their poles. The attitude of foresters may be indifferent, for they are aware of the large cavities in nearby living trees that may sometimes detract from the market value but they also know that the quantity of insects necessary to support a woodpecker, especially one as large as a Pileated, is significant.

A factor not often considered is the value of poles as nest sites. The birds are evidently attracted to poles because they offer certain advantages, but Rumsey (1970) found that woodpeckers nesting in newly-treated creosote poles were actually reducing their number of offspring. In 37 nests of Red-headed and six of Pileated Woodpeckers in newly-creosoted southern pine poles either the eggs did not hatch or the young died within a few days after hatching. Toxicity of the creosote caused 100 percent mortality of the embryos or altricial nidicoles. After several years the poles become safe as nest sites, but not until much of the preservative has volatilized. A general conclusion is that it would be advantageous to the birds to avoid nesting in treated poles, at least for several years after the treatment.

EXPERIMENTAL TESTS

Tests were conducted in an aviary and in the field. The aviary was used for preliminary screening of some of the treatments before they were tested in the field. Most of the field experiments can be divided into four main divisions: (1) tests used to investigate causes of woodpecker attack, (2) tests of methods to prevent attack, (3) tests used to investigate practices of repairing woodpecker damage, and (4) tests used to evaluate the effect of woodpecker damage to poles.

Aviary Tests

Description of aviary

The aviary (Figure 11) was located in Pineville, Louisiana, on property owned by the U. S. Veterans Hospital Administration. The aviary site was a relatively secluded area, surrounded by trees, and with resident woodpeckers in the immediate vicinity. The aviary was made of metal framing enclosed by 1-inch mesh poultry wire. It consisted of five contiguous cages, each measuring 10 x 20 x 8 feet with a 3- x 8-foot entrance gate. At various times Pileated, Red-headed, and Ladder-backed Woodpeckers (from south Texas) were confined.

Figure 11. Woodpecker aviary. (Pineville, Louisiana, 1967.)

Procedures.--Candidate repellents and overlays applied to short pole sections or fence posts were exposed to the birds. Also, laminated wooden sections of various sizes were placed in the aviary. The amount of damage by the birds to the treatments was noted.

Exploratory tests on electrical stimulation of the feet of a Red-headed Woodpecker were also conducted on a captive bird. A fence post was spirally wrapped with two conductors (wires) about 0.5 inch apart so that the perching bird would make contact scross the terminals. An AC transformer was used to apply voltage up to a maximum of 600 V.

Results and discussion.--Although adult birds were captured and successfully maintained in the aviary (Rumsey 1968), it was difficult to assess the birds' damage to test material, for the damage was sporadic and seemingly unoriented. Control material, that is, material with no treatment applied to it, was frequently damaged less than the test material. Tests with overlays and laminated wooden sections were also inconsistent. Birds had a tendency to perch on top of the pole sections and rectangular laminated sections and chip splinters from along the grain. In no instance did they make a completed cavity or test probe similar to those made outside the aviary. Laminates of redcedar (*Juniperus virginiana* L.) were splintered and damaged as were all the specimens in the other treatments, although redcedar fence posts in south Texas are immune to attack. Adding more redcedar oil to the sections failed to have an effect on amount of damage.

One possible solution to the woodpecker problem involves tapping electricity from the transmission lines and in some manner energizing a pole against woodpeckers' perching. In the aviary test a Red-head was not affected by a charge up to 600 V., a voltage impractical to exceed. A macroexamination of the bird's feet revealed them to be calloused, dry, and hard, with little tissue that would act as a conductor. Measurements with an ohmmeter showed little continuity through the bird's toes; they acted almost like an insulator. Further tests along this line did not seem warranted.

Conclusions.--I had anticipated that field tests would be necessary, and would be undertaken, after preliminary screening in the aviary. However, I did not obtain any leads in the aviary tests that warranted further experimentation in the field. The chief value of the aviary was that it provided close observations of birds in a relatively natural environment.

Field Tests

Description of study areas

Field tests were conducted mainly on four geographic locations: (1) in south Texas on the Laguna Atascosa National Wildlife Refuge, (2) in central Louisiana on the Saline Wildlife Management Area, (3) in central Louisiana near Bayou Boeuf, and (4) in west Louisiana along the Sabine River.

The Laguna Atascosa Refuge, operated by the U. S. Bureau of Sport Fisheries and Wildlife, is located northeast of San Benito, Cameron County, in the southern tip of Texas. It contains over 40,000 acres and is an important wintering area for many species of migratory birds. The vegetated ridges of the refuge support thick, thorny shrubs, cacti, and yucca intermixed with mesquite [*Prosopis juliflora* (Sw.) DC][2/], huisache [*Acacia farnesiana* (L.) Willd.], granjeno (*Celtis pallida* Torr.), and Texas ebony [*Pithecellobium flexicaule* (Benth.) Coult.]. Numerous trails for walk-in tours and "official use only" access roads transect the area. Small natural openings along these trails and roads offered suitable locations for the placement of fence posts for testing.

The Saline Wildlife Management Area (Figure 12) is located in LaSalle Parish about 25 miles northeast of Alexandria, Louisiana. The area, which encompasses approximately 60,000 acres of hardwoods, lakes, and bayous, is owned by the Louisiana Wild Life and Fisheries Commission. Prior to acquisition by the state, the area was periodically culled over by loggers with no apparent silvicultural plan. As a result most of the area contains irregular, uneven-aged stands that would not arrive at rotation age at short intervals indefinitely. Instead, the stocking is insufficient, many of the trees are crooked and limby, and the trees of merchantable size are mostly culls. The tract was used as open range for livestock until the late 1960's. Overgrazing was common and forest reproduction suffered as a result.

[2/] Nomenclature follows Little (1953) and Vines (1960).

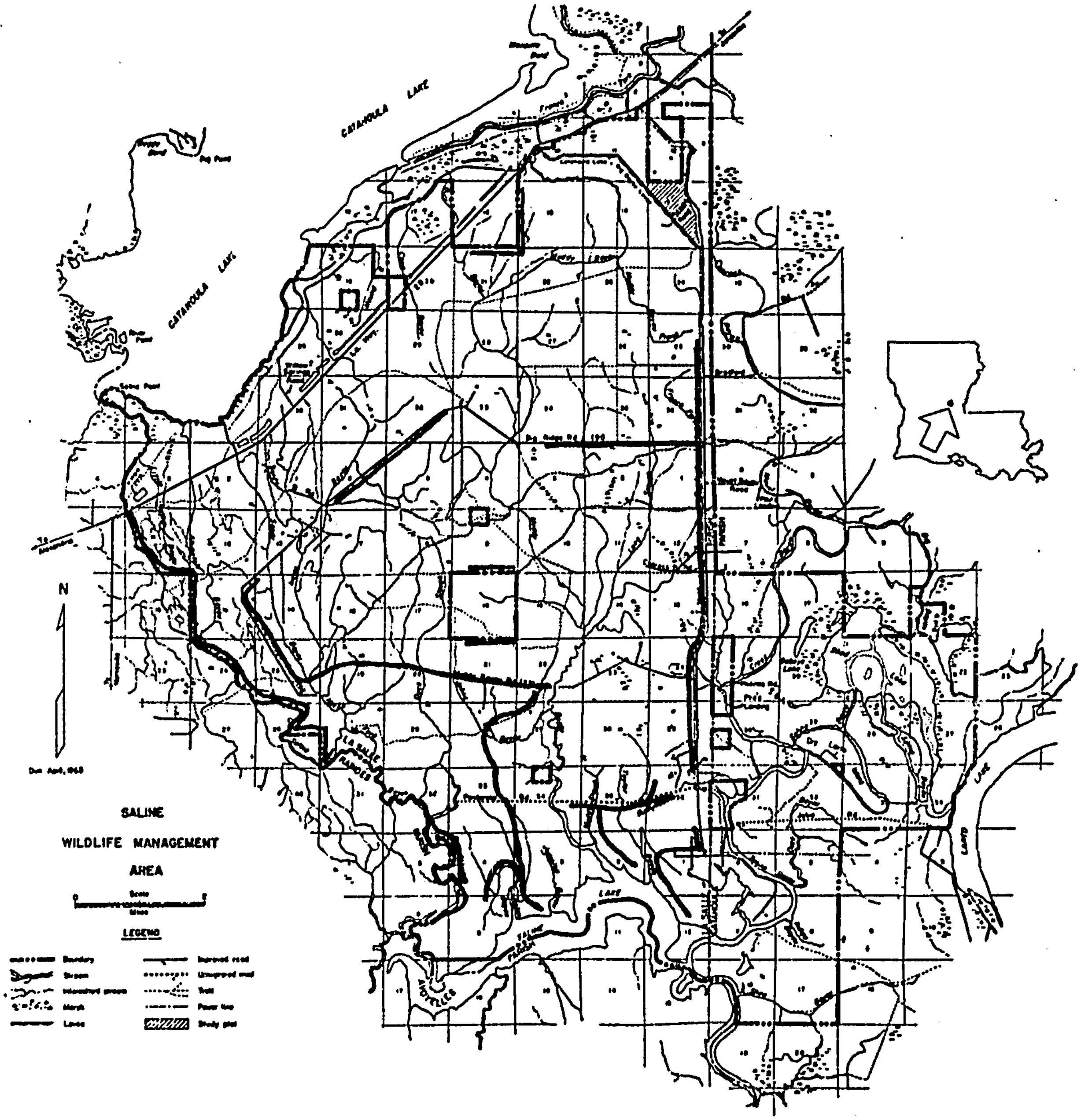


Figure 12. Saline Wildlife Management Area. Study poles were located along red lines. (Map courtesy of Louisiana Wild Life and Fisheries Commission.)

Much of Saline Wildlife Management Area is subject to annual backwater flooding from the Red River and Black River. Overcup oak (*Quercus lyrata* Walt.) and water hickory [*Carya aquatica* (Michx. f.) Nutt.] are the predominant overstory species where flooding occurs. Where flooding does not occur willow oak (*Quercus phellos* L.), Nuttall oak (*Quercus nuttallii* Palmer), American elm (*Ulmus americana* L.), cedar elm (*Ulmus crassifolia* Nutt.), green ash (*Fraxinus pennsylvanica* Marsh.), honeylocust (*Gleditsia triacanthos* L.), and persimmon (*Diospyros virginiana* L.) are present. Common shrubs of the overcup oak-water hickory type are swamp privet [*Forestiera acuminata* (Michx.) Poir.], hawthorns (*Crataegus* spp.), buttonbush (*Cephalanthus occidentalis* L.) and planertree [*Planera aquatica* (Walt.) Gmel.]. On the portion of the area less subjected to flooding Nuttall and water oak (*Quercus nigra* L.) are more abundant with water hickory absent. Also palmetto [*Sabal minor* (Jacq.) Pers.], smilax (*Smilax* spp.), and blackberries (*Rubus* spp.) replace buttonbush and swamp privet.

Numerous dead trees, many the result of oil-field activities, provide food and nesting sites for large populations of Pileated and Red-headed Woodpeckers. Two major roads, Hunt and Big Ridge, traverse most of the tract. Several spurs from these provide access to producing and abandoned well sites. Most of the study poles were placed along these existing roads and in rights-of-way along fences.

Bayou Boeuf is located in Rapides Parish in the alluvial plain of the Red River. The predominant overstory paralleling the operational utility line used in the study contains cut-over baldcypress (*Taxodium distichum* Rich.) and water tupelo (*Nyssa aquatica* L.) in the poorly drained flats and sloughs. Drier sites have been excessively cut over but contain young, near merchantable-sized cottonwood (*Populus deltoides* Bartr.), sycamore (*Platanus occidentalis* L.), hackberry (*Celtis laevigata* Willd.), boxelder (*Acer negundo* L.) and various red oaks. The understory on the wet sites is made up of buttonbush and its associated species. On the drier sites palmetto and hawthorns are present. The area is grazed by livestock but generally is not as poorly managed as was Saline Wildlife Management Area prior to its purchase by the Louisiana Wild Life and Fisheries Commission.

The utility line used for study in west Louisiana traverses first and second bottoms of the Sabine River in Vernon Parish. First bottoms contain stands of American beech (*Fagus grandifolia* Ehrh.), magnolia (*Magnolia grandiflora* L.), white oaks (*Quercus alba* L. and *Quercus prinus* L.) and some species of red oaks. The second bottoms contain a mixture of loblolly pine (*Pinus taeda* L.) and hardwoods such as hickory (*Carya* spp.) and blackjack oak (*Quercus marilandica* Muenchh.) on the drier, sandy sites. The loblolly is young and relatively small in diameter but quite tall. There is evidence of recent logging, but the area is not as mismanaged as the others already discussed. Cattle grazing is fairly heavy but does not seem to be excessive. The understory ranges from hawthorns and swamp privet on the wetter sites to waxmyrtle (*Myrica cerifera* L.) and beautyberry (*Callicarpa americana* L.) on the drier sites.

Conditions in poles conducive to woodpecker attack

Steaming, followed by a period of vacuum, is the established method of conditioning green or partially seasoned southern pine poles for creosoting (Edison Electric Institute 1964). If the steaming conditions are too severe, ring shakes (separations between annual rings) may develop (MacLean 1952). Examples are evident in Figures 13 and 14. The presence of these shakes (often called burst checks or steam checks by treating-company personnel) can usually be detected visually by the presence of a large check extending from the shake to the outer surface of the pole. I had observed that woodpeckers seemed to be attracted to those portions of the poles overlying such separations between the growth rings.

Procedures.--To test this hypothesis all shakes were located in 73 creosoted poles by observing the large checks and also by tapping the entire pole with a hammer. A total of 326 shakes were found and their periphery delineated with roofing tacks so they could be detected from the ground. The incidence of damage to the shake areas on a pole was compared to a predetermined area of equal size overlying sound wood. The test was conducted in two different areas: in west Louisiana along the Sabine River and in central Louisiana along Bayou Boeuf near Alexandria.

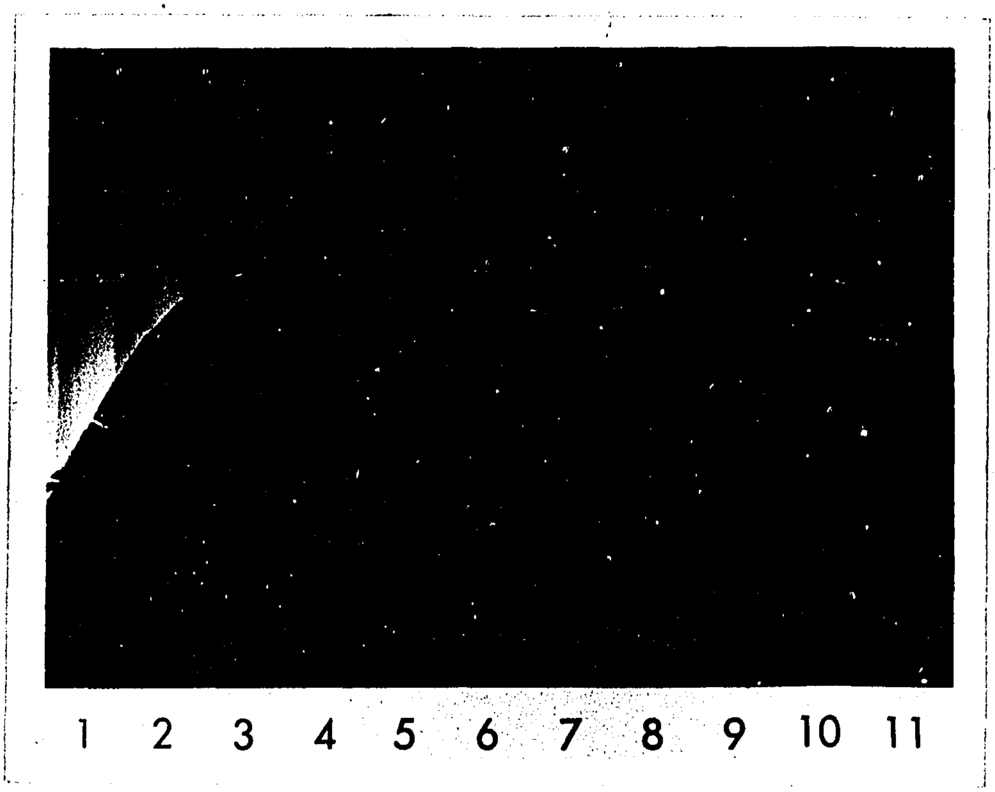


Figure 13. Ring shake in cross section of utility pole. Note check extending out to surface. (Scale in inches.)

Figure 14. This 2-inch thick slab extending over half the length of the pole is probably the result of treatment-induced ring shake. (Saline Wildlife Management Area, LaSalle Parish, Louisiana, 1971.)

Results and discussion.--Of the 33 poles examined along the Sabine River, only three were free of shakes. The remaining 30 had 176 shakes, or an average of 5.9 per pole. Woodpecker damage to the treatments is summarized in the tabulation:

Woodpecker attack	Test areas on poles		
	Shake	Sound	Total
	Number		
Damage present	9	0	9
Damage absent	167	176	343
Total	176	176	352

The total amount of damage was insufficient for valid conclusions. Eight of the poles with marked shakes (and paired sound areas) were damaged. Nine of the 176 marked shakes had some degree of damage, but there was none on the paired sound areas. Most of the damage was minor and consisted of shallow chipping. The greatest damage was a 2- x 3-inch hole extending 3 inches toward the center of the pole. There was also minor damage at 11 spots not in paired areas of the study.

The low incidence of attack to the poles is unexplainable. Pole-damaging woodpeckers were abundant in the area but for some reason were not prone to attack poles. One explanation could be the height of the overstory adjacent to the utility line. For the most part, the trees were much taller than the poles. During nesting seasons Pileated and Red-headed Woodpeckers usually select sites quite high from the ground and which have good vantage points. In that particular area trees would fulfill both criteria better than poles. However, I later observed high incidents of woodpecker damage to utility lines in a similar habitat in east Texas and southern Arkansas.

The second part of the experiment conducted along Bayou Boeuf near Alexandria was more fruitful. Of the 40 poles examined for the test, only six were free of shakes. The remaining 34 had 150 shakes, or an average of 4.4 per pole. (Because the line was energized, only those shakes below the crossarms were considered safe for study.) The 150 shakes were paired with sound areas of equal size and similar location as before. The results are tabulated below:

Woodpecker attack	Test areas on poles		
	Shake	Sound	Total
	----------Number----------		
Damage present	52	1	53
Damage absent	98	149	247
Total	150	150	300

During the two years of the test, 33 of the 34 poles with marked shakes (and paired sound areas) were damaged by woodpeckers. There was excavating in 52 of the 150 marked shakes, but in only one of the marked sound areas. Although most of the damage was minor, nine areas on six poles had heavy damage--the holes extended into the mid-point of the poles.

Not all damage was associated with marked shake or shake-free areas (Table 2). There were 98 spots damaged that were not in either the marked shake or shake-free areas. Twenty-eight of those were at presumed shakes, on the basis of the presence of burst checks (Figure 15). Those areas were not included in the formal study because they were too close to conductors for safe work by research personnel. The remaining 70 excavations were at locations free of burst checks and, hence, presumably free of internal ring separations.

Table 2. Incidence of woodpecker damage to 40 creosoted southern pine test poles

Pole number	Number of pairs of shake and sound areas	Where damage occurred: Marked shake areas	Marked sound areas	Unmarked shake areas	Unmarked sound areas	Total
		Number				
1	4	2	0	3	0	5
2	1	1	0	0	0	1
3	4	3	0	0	0	3
4	6	1	0	0	0	1
5	5	5	0	4	3	12
6	2	1	0	0	3	4
7	0	0	0	0	3	3
8	4	4	0	1	1	6
9	7	1	0	0	2	3
10	3	3	0	0	0	3
11	10	3	0	0	1	4
12	3	0	0	0	0	0
13	9	1	0	0	0	1
14	4	4	0	7	0	11
15	3	0	0	1	2	3
16	3	3	0	3	1	7
17	14	5	0	4	0	9
18	6	2	0	1	0	3
19	1	0	0	0	1	1
20	14	0	0	0	1	1
21	1	0	0	0	1	1
22	0	0	0	0	3	3
23	0	0	0	0	3	3
24	2	0	0	0	4	4
25	2	2	0	0	3	5
26	7	4	0	2	2	8
27	1	0	0	0	2	2
28	1	1	0	1	3	5
29	1	1	0	0	6	7
30	1	1	0	0	4	5
31	5	2	0	0	2	4
32	7	2	1	0	4	7
33	0	0	0	0	0	0
34	5	0	0	0	5	5
35	4	0	0	0	3	3
36	5	0	0	0	1	1
37	2	0	0	0	5	5
38	0	0	0	0	1	1
39	0	0	0	0	0	0
40	3	0	0	1	0	1
Total	150	52	1	28	70	151

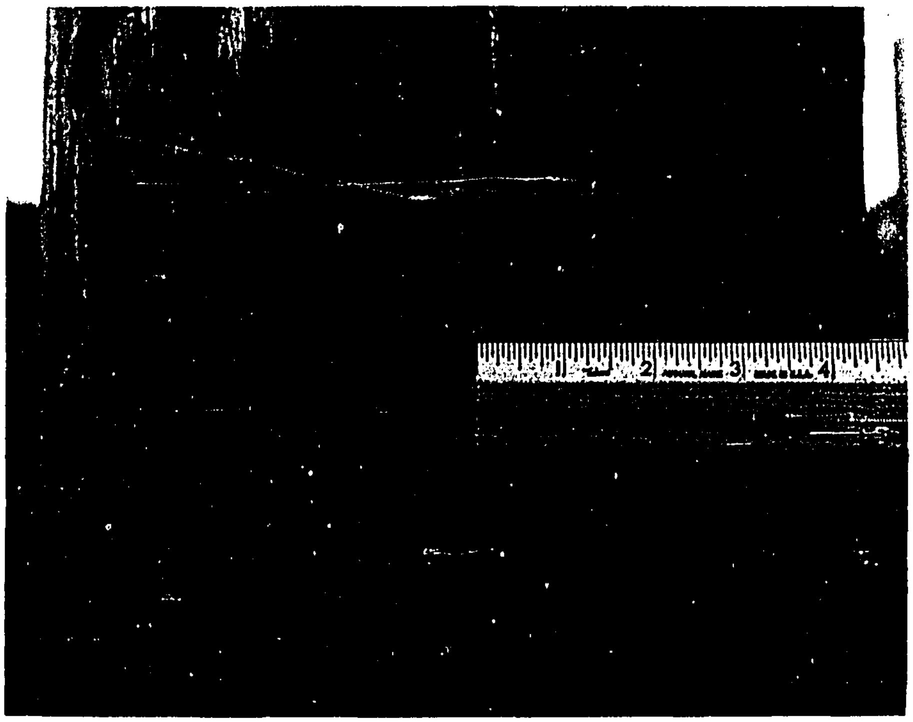


Figure 15. Burst checks of this size extend inward to a separation between annual rings.

It should be recognized that most of a pole is free of shakes, so the 71 damaged sound areas represent a much smaller incidence of attack than the 80 areas with shakes that were damaged. For example, a class 4, 45-foot pole, which is the size of those used in this study, has over 100 square feet of total surface area. However, since woodpeckers do not normally inflict damage to the lower 8 linear feet above groundline, a total of about 70 square feet is actually subject to attack. Shake areas on these poles averaged about 1 square foot (6 x 24 inches) and there were about five per pole (including those that were not marked). Consequently, 5 square feet of the vulnerable pole surface were over shake areas leaving about 65 square feet over sound portions of the pole. The incidence of attack in this study, then, was about one per 2.1 feet of shake area but only one per 31.1 feet of sound area.

Most of the damage to marked and unmarked shakes occurred during the first nesting season. However, damage to unmarked sound areas increased more after the first season. This illustrated further that woodpeckers were attracted to shakes initially.

Only a superficial effort was made to determine the species of woodpeckers doing the damage. As is often the case, Pileateds appear to have started most of the work with Red-headed Woodpeckers moving in later. However, Pileateds do not seem to be driven out as a result of competition. Instead, they appear to make many test probes and leave, and the opportunistic Red-heads are willing to complete some of these excavations.

Conclusions.--Since it is apparent that woodpeckers are attracted to shakes, the paramount question is, what would be the outcome if only shake-free poles were used in a utility line? On the basis of this experiment, and observations on the amount of damage on Cellon poles (13 without shakes) used in a later experiment, it appears that woodpeckers will still attack poles. However, the four shake-free creosoted poles mentioned earlier suffered mostly superficial attack, the largest hole being a 2- x 2-inch test probe 1 inch deep.

Preventing attack

Poles used in tests designed to prevent woodpecker damage were in one of the following categories: coated, wrapped, treated with various preservatives, laminated, manufactured from an especially dense species of timber, or were treated with one or more of numerous chemicals.

Fence posts were used in some tests because they were much easier to manipulate and were much cheaper than poles. Also the amount of experimental material needed to coat a post is insignificant when compared to that for a pole. And, as stated earlier, Ladder-backed and Golden-fronted Woodpeckers readily damage fence posts in south Texas.

Comparison of Hard and Soft Fence Posts

Since there must be some degree of hardness impenetrable by woodpeckers, and I had no idea what that quantity was, I performed an experiment in which I compared the incidence of attack to hard and to soft southern pine fence posts. I was also interested in determining if woodpeckers would show a preference for softer wood when given a choice. It is known that there is considerable variation in the hardness of the southern pines. However, since there is no satisfactory method of identifying the species anatomically, they are lumped and referred to as southern pine. It is possible that two or three species were included in the experiment on effect of hardness. All posts were purchased from one creosoting company, but some had been on the yard approximately 6 months while others had been treated up to 18 months. No differences in hardness were attributed to the length of time the posts had been on the yard, although moisture content has a drastic effect on hardness.

Procedures.--Hardness values were determined in the laboratory for 102 creosoted posts which were 4.0 to 4.5 inches in top diameter and 6.5 feet long. The hardness values represent the amount of force (pounds) necessary to embed a 0.444-inch "ball" to a depth of one-half its diameter into the post. Three measurements were taken 120° apart near the middle of each post and an average value calculated for that post. The range of 433 to 1,417 pounds approximated a normal distribution. Twenty of the softest posts (433 to 777 pounds) and 20 of the hardest (1,130 to 1,417 pounds) were paired for testing at Laguna Atascosa

National Wildlife Refuge. The amount of damage to the two types of posts was compared using a paired t test.

The following scheme was used to appraise the amount of damage to posts and poles throughout the study:

Value	
0	No damage
1	Peck marks
2	Check work or channeling
3	Test probe less than 1 inch inward
4	Test probe 1 inch or more inward but with no downward excavation
5	Downward excavation less than 2 inches
6	Downward excavation greater than 2 inches, or completed cavity

When more than one category of damage was present on an experimental unit, the damage values were added to give an overall damage index. I recognize that a completed cavity is more than six times as detrimental as peck marks. However, the evaluation seemed sufficient.

Results and discussion.--The post arrangement, hardness, and total amount of damage on the 20 pairs are presented in Table 3. Twelve of the hard posts and 16 of the soft were attacked. By using the damage rating scheme listed above, a value of 56 was calculated for the hard posts and 96 for the soft. The difference was not statistically significant ($P > .05$).

Also, on the chance that the amount of minor damage may be concealing a difference in severe damage between the treatments, a separate analysis was made using only posts containing damage values of 4, 5, or 6. A t test statistic of 1.16 was calculated which is obviously not significant.

Table 3. Amount of woodpecker damage to 20 hard and 20 soft fence posts after 5 years' exposure

Pair number	Post number	Hardness	Total damage	Pair number	Post number	Hardness	Total damage
		Pounds	Index value			Pounds	Index value
1	7	730 (S)	7	11	5	733 (S)	6
	26	1417 (H)	12		85	1153 (H)	0
2	70	1197 (H)	15	12	4	720 (S)	0
	44	767 (S)	0		60	1393 (H)	0
3	9	637 (S)	1	13	91	660 (S)	4
	36	1390 (H)	0		14	1293 (H)	0
4	84	753 (S)	3	14	42	747 (S)	0
	23	1163 (H)	0		59	1200 (H)	0
5	50	1157 (H)	1	15	12	700 (S)	4
	37	747 (S)	3		49	1328 (H)	2
6	69	1190 (H)	5	16	20	710 (S)	10
	64	700 (S)	6		54	1130 (H)	0
7	94	657 (S)	11	17	58	1263 (H)	5
	73	1417 (H)	8		75	777 (S)	11
8	82	717 (S)	10	18	19	1193 (H)	4
	22	1170 (H)	1		83	630 (S)	7
9	33	1260 (H)	1	19	68	717 (S)	4
	11	433 (S)	6		67	1377 (H)	1
10	62	733 (S)	0	20	46	773 (S)	3
	87	1337 (H)	0		90	1163 (H)	1

The amount of damage increased over the 5-year period of the study, but not consistently (Table 4). At the time of the first observation the posts had been in test about 8 months. In the fall of 1967 a severe hurricane struck the study area and apparently reduced the woodpecker population, as seen by the low rate of woodpecker damage shortly after that time. Evidently as the population increased, the rate of damage also increased.

Conclusions.--Two important facts were obtained in this experiment. First, there is not a natural hardness in the southern pines sufficient to deter woodpecker attack. (This is discussed further in a test with poles.) And second, damage does not occur for a short time and then drop off markedly as reported in the literature; in this test it increased considerably in the last two years.

Coated Fence Posts

Not only is there a hardness that woodpeckers cannot penetrate, although that hardness does not occur naturally in species of timber used for poles, there is also a smoothness they cannot cling to. Coatings were selected and applied to fence posts to provide further information on qualities of smoothness and hardness necessary for repellency.

Procedures.--Fifty fence posts with five treatments replicated in 10 blocks were used. The posts were erected at Laguna Atascosa National Wildlife Refuge. Spacing between posts was approximately 50 yards. A description of the treatments follows:

Table 4. Increase in amount of woodpecker damage to 20 hard and 20 soft fence posts during the 5-year period of the study

Date of observation	Amount of damage[1/] On hard posts	On soft posts	Total
8/13/67[2/]	12	28	40
2/7/68	13	37	50
4/23/68	13	38	51
2/12/69	13	49	62
5/27/70	30	85	115
3/22/72	56	96	152

[1/]Based on rating scheme shown on page 51.

[2/]The posts had been in test eight months at the time of the first observation.

1. 10 posts coated with Epibond 8083, a two-part, nonflowing epoxy formulated for bonding metal surfaces even when a slight film of oil is present. Curing time is 24 to 36 hours and results in a hard, smooth coating.

2. 10 posts coated with Wey-fil, a two-part nonflowing epoxy used by Weyerhaeuser Company in the manufacture of plywood. Curing occurs within 10 to 15 minutes with a hard, somewhat grainy surface the result.

3. 20 posts--10 each coated with the two epoxies mentioned above plus a coating of finely crushed rocks. The rocks were washed and sifted between No. 4 and No. 8 screens (openings of 0.187 inch and 0.0787 inch). After the application of Epibond and Weyfil, but prior to their curing, the posts were placed in round cylinders 8 inches in diameter and 4 feet in length, and the rocks poured in around the posts. After the epoxies cured, the cylinder was removed, the surplus rocks permitted to fall away, and a coating of rocks was retained in the adhesive.

4. 10 posts with no coating used as controls.

The amount of damage to the treatments was compared by using the rating scheme mentioned earlier.

Results and discussion.--Coated fence posts were in test for slightly over 5 years. During that period only eight of the 50 posts were damaged, and the most serious damage was a test probe 3 inches inward. The following tabulation shows the number of posts damaged in each treatment:

Treatment	No. of posts damaged
Control	2
Epibond	4
Wey-fil	2
Epibond and rocks	0
Wey-fil and rocks	0
Total	8

The lack of damage on these posts is puzzling, since the posts used in the hardness test were located nearby in the same habitat and over half of them were damaged. Furthermore, most of the coatings had deteriorated badly by the end of the study and would have offered no barrier to woodpeckers. Degradation was greatest to those coatings without rocks. However, during the fifth year the treatments with rocks deteriorated also. Round, creosoted surfaces are very difficult to coat because of configuration and the oily exterior. On the basis of the small amount of damage, any analysis of the data would be of doubtful value.

Conclusions.--With the exception of information on the durability of the coatings, little worth-while information was obtained.

Coatings and Wrappings on Round Poles

Research in this area involved several tests with coatings (materials applied directly and bonded to the poles) and wrappings (materials not bonded to the poles but held in place by tacks, nails, or an overlapping bond to itself).

Procedures.--Experiment A was a 2 x 2 x 2 factorial arrangement of treatments with all combinations of two basic pole conditions (poles with and without shakes), two coating conditions (coated or not coated), and two decoy conditions (presence or absence). A total of 56 class 2, 50-foot southern yellow pine poles was used. The eight treatments were replicated seven times in a randomized block design. Shakes were not marked with tacks as was done previously; instead the entire pole was considered to have, or to be free of, shakes. Twenty-six poles were kiln-dried prior to creosoting in an unsuccessful attempt to avoid internal ring shakes. The remaining 30 were steam-conditioned and creosoted in the conventional manner. Retention of creosote in each process was 10 pounds per cubic foot of wood. Seven of the poles appeared to be free of shakes; the other 49 averaged 56 shakes per pole. Since 28 of the poles were used as "no shakes," and this condition was not met in the manufacturing process, pieces of 2 x 2 hardware cloth were used to mechanically prevent the woodpeckers from attacking those spots. For statistical evaluation, pieces of hardware cloth were stapled over comparable areas on sound poles.

On 28 of the poles, a coal tar-epoxy coating (Koppers' 300-M) was applied to the top 35 feet. Approximately 7 to 8 feet of uncoated pole were exposed above groundline, but attack that low is very rare. The coating had produced a hard, smooth surface when applied to 8-foot sections by technicians of Koppers Company. However, a spray application to creosoted poles in direct sunlight did not prove satisfactory. Immediately after application the creosote began bubbling out through the uncured coating and produced numerous small holes, resulting in a rough surface. The faulty coating was scraped from the poles, a shelter erected for shade, and a new coating applied with brushes. This application appeared completely satisfactory until the poles were erected, when some bleeding occurred. Touch-up work was necessary to repair damage inflicted during transport and placement.

Another feature of this experiment was an attempt to direct birds' activity away from a pole to a much cheaper decoy. Accordingly, on 28 of the poles (14 coated and 14 uncoated), a 7-foot creosoted section of cottonwood approximately 12 inches in diameter was bolted to each. The top of the section was 10 feet down from the top of the pole, a location believed to be most conducive to woodpecker attack (Figure 16). A 4-digit numbered tag was affixed to each pole. The first digit denoted the block number, and the other three the presence or absence of shakes, coating and decoy in that order; a "1" signified presence and "2" absence. For instance, pole #4121 was in the fourth block, it contained shakes, did not have a coating, but did have a decoy. All poles were placed on Saline Wildlife Management Area at intervals of approximately two-tenths of a mile apart, or roughly twice the distance normally used by utility companies. This spacing was believed sufficient to minimize an individual

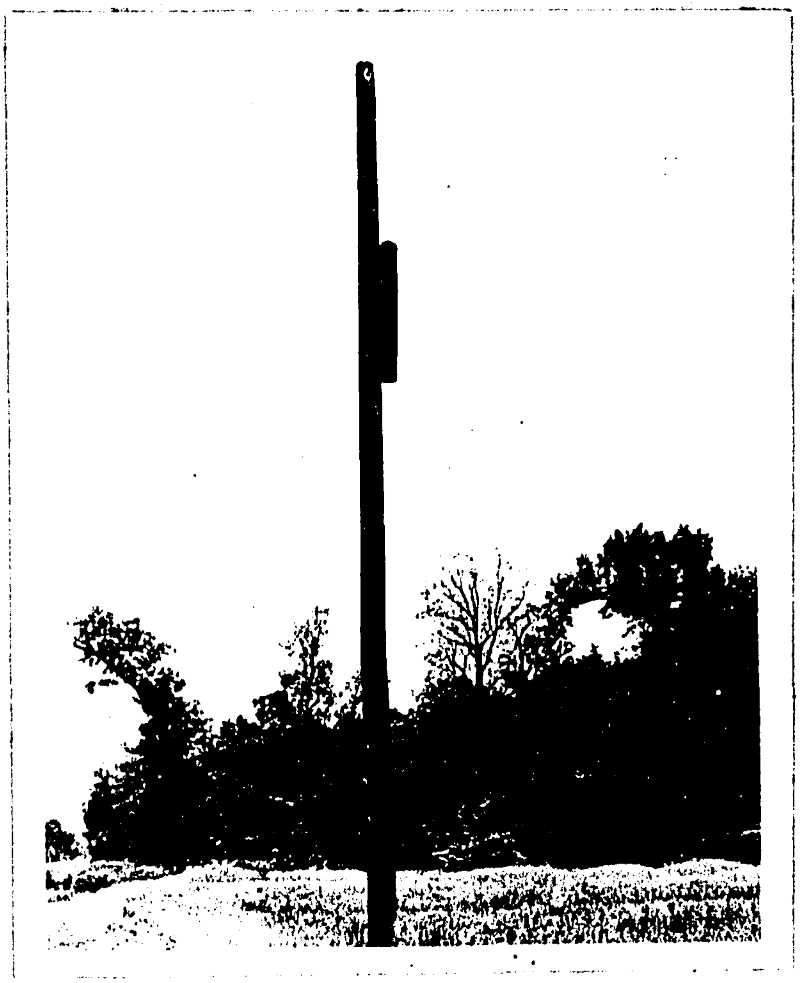


Figure 16. Decoys were mounted on poles at the most susceptible height to attract woodpeckers. (Saline Wildlife Management Area, LaSalle Parish, Louisiana, 1969.)

bird having a choice of poles or treatments. The random assignment of treatments within blocks is shown in Table 16, page 130.

After it was apparent that it would be difficult to coat creosoted poles, 14 Cellon poles were obtained and a coating applied to them. (This portion will be referred to as Experiment B). Cellon processed poles are impregnated with pentachlorophenol in a liquefied alkane carrier. The end result is a clean, nonoily product suitable for painting. Koppers' 300-M was again used as the coating.

On seven of the 14 class 2, 50-foot southern pine poles the top 35 feet were coated. The other seven were not coated and served as controls. Poles were placed in Saline Wildlife Management Area at distances of two-tenths of a mile apart. The amount of damage (as calculated from the scheme presented earlier) was evaluated with a paired t test.

Experiment C involved a further test with the 56 poles used in Experiment A. Two new concepts were introduced: a polyurethane wrap was used and hollowed-out sections of white pine (*Pinus strobus* L.) were substituted for the cottonwood decoys. The wrap, a rubber like polyether-based polyurethane produced by the B. F. Goodrich Company, was applied to the top 35 feet of the 50-foot poles. The material was stapled to the poles; several pieces were applied in bands from the tops of the poles downward.

Also, 7-foot sections of creosoted white pine, 12 to 15 inches in diameter, were bolted on 28 of the poles (14 wrapped and 14 unwrapped). The sections had been quarter-sawn, a 2-foot long portion of wood removed from the center of each quarter, and the pieces glued back together in a manner concealing the internal cavity (Figure 17). They were attached 10 feet down from the tops of the poles.

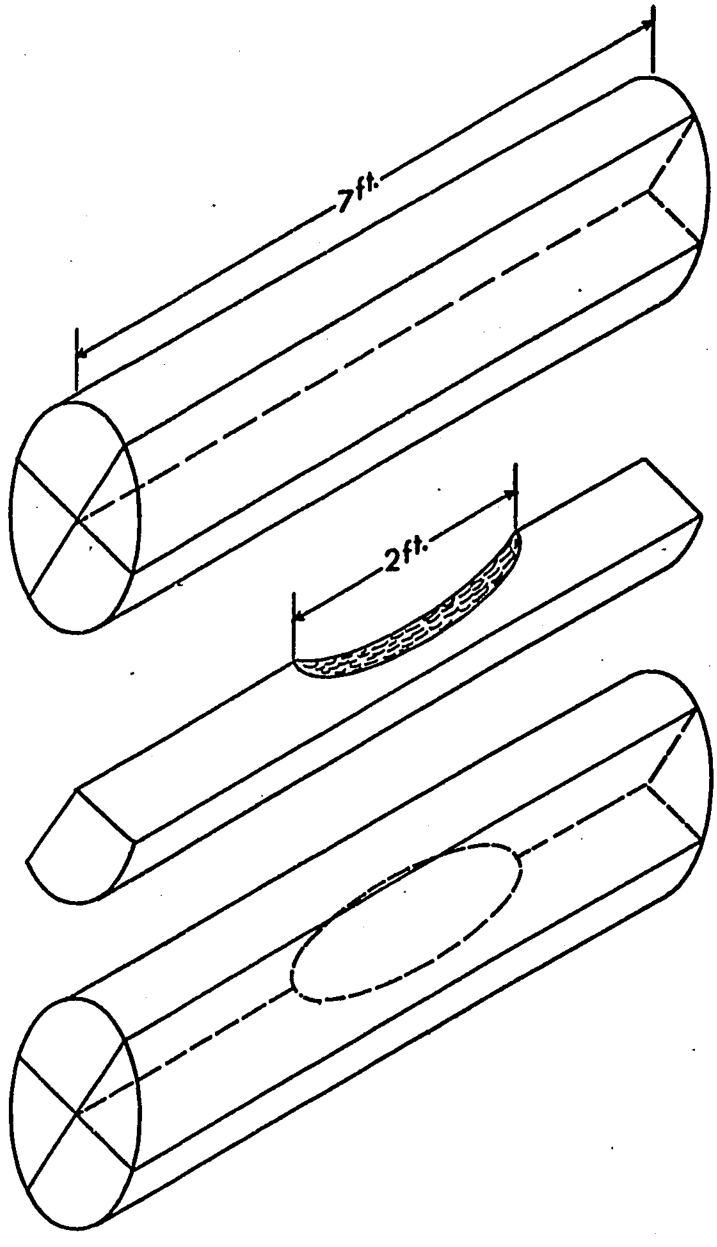


Figure 17. Sections of white pine were quartered, two feet of wood chiseled out of each quarter, and the four pieces laminated together so that the internal cavity was invisible.

Experiment D was a further evaluation of coatings on Cellon poles. It also included an abortive attempt to evaluate laminated poles--abortive because vandals cut down and removed four of the six poles in the test. Seventy-two class 5, 45-foot southern pine poles were placed in good woodpecker habitat in Saline Wildlife Management Area.

There were seven brush-on coatings included in the experiment, each of which had been exposed in prior small-scale fence post tests. Some of the materials were selected primarily for hardness; others were chosen for smoothness. Durability and economics were considered, also. A brief description of each treatment follows:

1. Polyester--this is the liquid component that is applied with cloth when fiberglassing.
2. Koppers' 200 epoxy--a blue-gray epoxy but available in other colors.
3. Baker's EC-167 and cheesecloth--a vinyl urethane coating developed to meet the requirements of the American Plywood Association for Exterior Sanded and Medium Density overlaid plywood. Cheesecloth was used to bridge the weather checks.
4. B. F. Goodrich's 0500 BH 176--a two-part epoxy adhesive used for bonding metal, glass, ceramic, wood, etc.
5. B. F. Goodrich's 7802--an elastomeric polyurethane recommended for use where a tough abrasion-resistant coating is desired. It is used for coating automotive and marine rubber goods.
6. Fiberglass--fiberglass cloth and polyester make up the complete treatment used when covering boats, repairing fiberglass automobile fenders, etc. For very smooth finishes a layer is applied, sanded after it has cured, and then another layer applied.

7. Weyerhaeuser's Wey-fil--an epoxy used in the manufacture of plywood. It has some promise as a woodpecker hole filler since it restores some strength to poles through its adhesive properties.
8. Control--an uncoated Cellon pole.

Coatings were applied only to the top 30 feet. Approximately 5.5 feet of each pole were placed in the ground, so there was an exposed untreated section of 8 to 10 feet.

In addition to the Cellon poles, there were six, 40-foot, approximately 8-inch square, laminated poles that were furnished by Weyerhaeuser Company. Three were treated with penta-oil and the others by the Chemonite process, a patented process using ammoniacal copper arsenite (ACA). All were made from Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco.].

The poles were spaced approximately one-tenth of a mile apart along the edge of a 40-foot fence right-of-way. Each pole was numbered with a plastic tag approximately 6 feet above groundline. The tag contained a number that represented the block and a letter denoting the treatment. Treatment letters corresponded to those listed above. For instance, "1A" referred to the first block and the pole was coated with polyester.

The treatments were blocked to permit isolation of variation due to location. There were nine blocks with the eight treatments assigned at random within each block. The arrangement of poles is shown in Table 17. The amount of damage based on the damage value index was the criterion for comparison.

Another wrap, a proprietary product called Vaughn Bar-Bird Pole Shields, was tested separately in Saline Wildlife Management Area. The shields are made from polyethylene plastic and are manufactured in 16-foot lengths, in widths of 10.5 or 14 inches. The strips are spirally wrapped from the top of a pole downward, with the lowermost winding pushed up under the flange of the preceding, thus preventing woodpeckers from obtaining a toehold. Sixteen creosoted southern pine poles--eight class 5, 45-footers in a low voltage distribution line and eight class 2, 50-footers with no attachments--were wrapped. The amount of damage was compared to controls in the area.

Results and discussion.--Shown in Table 5 is the amount of woodpecker damage on the 56 poles in test to determine the effect of shake, coating, and decoys (Experiment A). Thirty-four of the poles had some degree of attack after 15 months; 11 of them contained completed cavities. The most prevalent damage--category 4--consisted of small, shallow holes that extend 1 inch or more inward but with no downward excavation. These appear to be test probes, since several of them were made before a large cavity was started. There were 13 severe excavations--categories 5 and 6--on 13 poles; no pole had more than one completed or nearly completed cavity. The minor damage averaged about three incidences of attack per pole.

The damage index per pole varied from 0 to 78 with a total of 507 (Table 6). These data were evaluated with an analysis of variance (Table 18, p. 133); coated poles were damaged less than uncoated poles, and poles with decoys were also damaged less than poles without decoys. The effectiveness of the decoys in reducing total damage was not in the

Table 5. Incidence of woodpecker damage, per damage value categories, on 56 creosoted test poles

Damage category	Poles with that type of damage[1/]	Frequency of damage
	----Number----	
0	22	--
1	18	41
2	16	23
3	3	8
4	25	80
5	2	2
6	11	11
Total	(2/)	165

[1/] Thirty-four of the 56 poles had some damage.

[2/] Sum is of no meaning since many poles had more than one category of damage.

Table 6. Damage index[1/] for eight treatments in pole-coating study

Treatments	Blocks 1	2	3	4	5	6	7	Total
	Damage index							
Shake-coating-decoy	0	0	0	1	0	6	0	7
Shake-coating-no decoy	2	6	0	5	10	0	0	23
Shake-no coating-decoy	19	25	0	17	13	8	0	82
Shake-no coating-no decoy	35	11	4	4	16	33	7	110
No shake-coating-decoy	0	6	0	0	0	0	0	6
No shake-coating-no decoy	8	0	0	0	0	0	0	8
No shake-no coating-decoy	3	12	2	9	9	7	28	70
No shake-no coating-no decoy	19	31	78	30	18	17	8	201
Total	86	91	84	66	66	71	43	507

[1/]This represents the sum of the damage values, which were based on incidence of attack x the assigned value for that type of damage.

manner anticipated. They were included to attract birds and thereby prevent damage to the poles. However, only three of the 28 decoys were attacked, and damage was minor in all cases; birds pecked around the bolts used to attach the decoy sections to the poles. It appeared that the decoys functioned as scarecrows in reducing attack. If indeed that was the function of the decoys, their effectiveness would be of dubious value, because the effectiveness on birds of scaring devices is usually short lived.

There was no difference in amount of damage on poles with or without shakes. But most of the damage to poles with shakes occurred at the areas overlying the shakes. As in an earlier study, it appeared that when the woodpeckers had a choice for exploration they chose the shake area. However, it is important to note that this is merely a preference, and sound poles are subject to attack when a choice of locations is not available.

While there were significant differences between the treatments, the most effective failed to give an acceptable level[3/] of protection. Two of the 14 sound, coated poles were damaged, and one of those had a completed cavity--damage serious enough to warrant changing-out of the pole if it were in a utility line. In fact, some of the cooperating companies would change-out both of the poles. Assuming that most single-pole structures average about 10 poles per mile, this would necessitate changing over one pole per mile. And this damage occurred over a 15-month period, a relatively short time of exposure for a creosoted pole.

[3/] Although not specifically defined, "acceptable level" would be near the success achieved with hardware cloth.

The following tabulation includes all damage on the seven pairs of Cellon poles in Experiment B after 24 months' exposure.

Pair number		Damage index Coated	Uncoated
1		10	33
2		5	17
3		8	36
4		6	21
5		7	12
6		17	17
7		27	23
	Total	80	159

The amount of woodpecker damage on the poles coated with Koppers 300-M was significantly less ($P < .05$) than on uncoated poles ($t = 2.53$; 6 d.f.). However, the amount of damage on coated poles was far above an acceptable amount. There was no damage on any poles for the first 7 months of the test, but after that time the coating deteriorated and peeled, allowing woodpeckers to begin attack.

The treatments used in Experiment C (shakes, a polyurethane wrap, and hollow sections of white pine decoys) were in test 28 months. Woodpecker attack was present on 30 of the 56 poles. A summary of severity of damage includes:

22 poles with severe damage--completed cavities or holes at least 3 inches in diameter

3 poles with holes 2 to 3 inches inward and not listed above

5 poles with lesser damage and not listed above

30 Total

A tabulation of damage on all treatments follows:

Treatments: Shake	Treatments: Wrapping	Decoy	Total number of poles damaged	Mean damage index	Number of poles damaged severely[1/]	Mean index of severe damage
Yes	Yes	Yes	0	0	0	0
Yes	Yes	No	1	0.9	1	0.9
Yes	No	Yes	7	10.9	4	3.4
Yes	No	No	7	13.1	5	7.4
No	Yes	Yes	1	1.0	1	1.0
No	Yes	No	0	0	0	0
No	No	Yes	7	12.4	4	4.3
No	No	No	7	25.3	7	10.3
			30		22	

[1/] Completed cavities or holes 3 inches and larger in diameter.

The amount of damage on each pole and the analysis of variance are presented in Tables 7 and 19, respectively. Poles with wrapping were damaged significantly less ($P < .01$) than poles with no wrapping, poles with shakes were damaged less ($P < .05$) than poles without shakes, and poles with decoys were damaged less ($P < .05$) than poles without decoys.

Table 7. Woodpecker damage (based on a damage value index) on 56 study poles

Treatments	Blocks 1	2	3	4	5	6	7	Total
Shake-wrapping-decoy	0	0	0	0	0	0	0	0
Shake-wrapping-no decoy	0	0	0	0	6	0	0	6
Shake-no wrapping-decoy	6	8	6	20	16	18	2	76
Shake-no wrapping-no decoy	10	16	11	14	12	19	10	92
No shake-wrapping-decoy	0	0	0	0	0	7	0	7
No shake-wrapping-no decoy	0	0	0	0	0	0	0	0
No shake-no wrapping-decoy	22	18	4	17	4	6	16	87
No shake-no wrapping-no decoy	22	13	37	14	34	22	35	177
Total	60	55	58	65	72	72	63	445

Actually, the analysis was not necessary to determine that the polyurethane wrapping was effective. There were only two instances where the wrapping itself failed. On another pole, a woodpecker perched on top of a decoy section and tore the polyurethane. Birds damaged five poles below the wrapping (only one severely) indicating that poles should have been wrapped closer to the ground. Birds do not normally damage poles so near the ground. It is probable that they reacted somewhat abnormally, since they were thwarted from the portion of pole normally attacked.

In this experiment and others it was evident that woodpeckers initially attacked poles at shakes, but this apparently does not lead to greater overall damage. For, while there was exploratory pecking and enlargement of the checks in poles with shakes, birds used shake-free poles significantly more for serious excavations. The following tabulation shows the comparison.

Condition of pole	Number of holes by average size of opening: Completed cavity	4 inch	3 inch	2 inch	1 inch	Peck work
Shakes	9	1	4	10	11	26
No shakes	12	1	8	26	16	12

Field observations reveal that woodpeckers often stop working at a shake after they have pecked through the outer layer of wood. Apparently, when the hollow sound is no longer produced by tapping, the birds lose interest. It is likely that the hollowed-out decoys gave stimulating sounds until the bird actually broke through into the cavity. This could account for the high incidence of serious damage to

the decoys. The severity of damage to poles with decoys was significantly less than to poles without decoys. However, this fact may be misleading, since the number of poles damaged in the two treatments was equal--15, far exceeding an acceptable level. Woodpeckers were definitely attracted to the decoys (Figure 18). Birds excavated into each of the 28 internal cavities and nested in several. Young were hatched in some, but it is not known if any fledged. At least one decoy was used by flying squirrels (*Glaucomys volans*) and a wood duck (*Aix sponsa*) was flushed from another.

The Cellon poles in Experiment D were in test 30 months, which encompassed three nesting seasons. Differences in amount of damage between treatments were significant (P <.05) (Table 20, p.135), but all treatments were damaged above an acceptable level. Wey-fil had the smallest amount of damage--significantly less than Koppers' 200 and the two B. F. Goodrich products, but not less than the control. The number of completed cavities ranged from one on Wey-fil-coated poles to 12 on BFG 0500; most of the treatments had 3 to 5 (Table 8). Within each treatment, at least three of the nine coated poles were damaged; and three of the treatments had eight of the nine poles damaged (Table 9). This high incidence of attack indicates that woodpeckers had little difficulty penetrating the coatings, most of which deteriorated badly during the course of the study. Wey-fil was the most durable while the two BFG products and Koppers' 200 were the least durable.

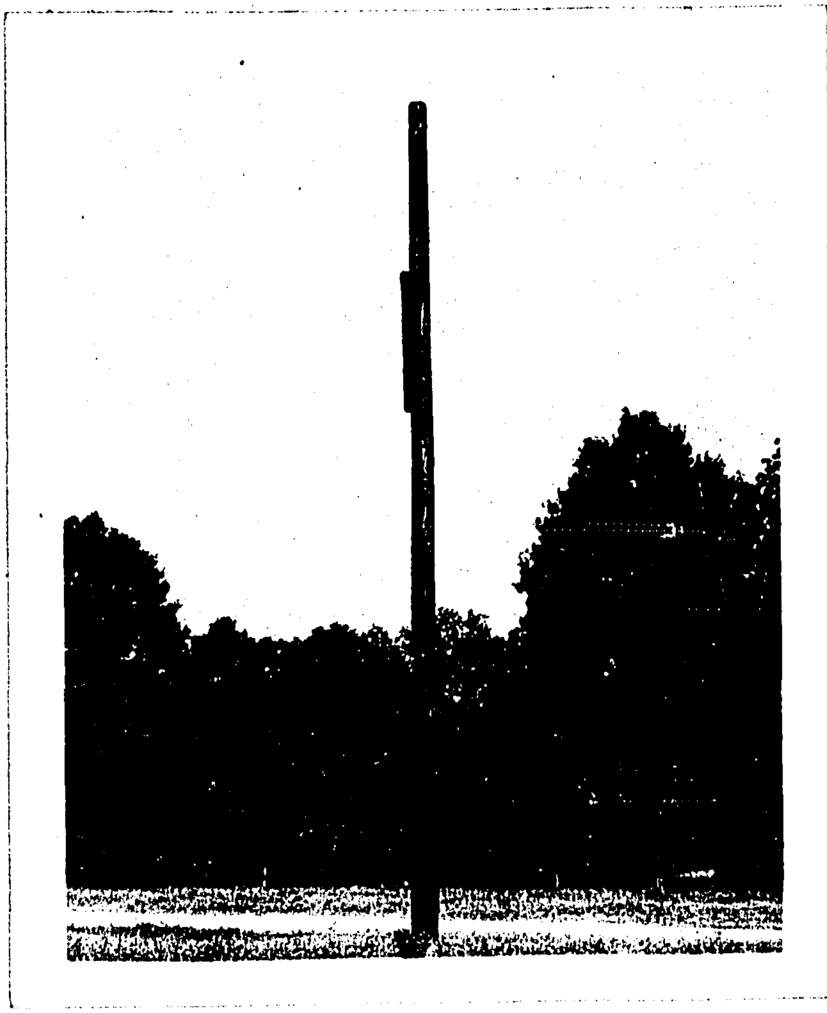


Figure 18. Hollow sections were used extensively by woodpeckers, but the birds also damaged the poles. (Saline Wildlife Management Area, LaSalle Parish, Louisiana, 1969.)

Table 8. Severity of damage to coated Cellon poles exposed to woodpeckers for 30 months

Treatments	No. of completed cavities	No. of incompleted cavities by diameter 1 inch	2 inch	3 inch	4 inch	5 inch
Polyester	1/3(2)	1(1)	4(2)	2(1)		
Koppers' 200	5(5)	4(3)	8(4)	3(2)	1(1)	1(1)
Baker's EC-167	4(3)	3(2)	3(3)			
BFG 0500	12(6)	11(6)	12(5)	2(2)	1(1)	
BFG 7802	4(4)	16(6)	7(3)	2(2)	4(2)	
Fiberglass	4(2)	3(2)	1(1)			
Wey-fil	1(1)	1(1)	1(1)	1(1)		
Control	4(4)	4(4)	6(4)	8(3)		
Total	37(27)	44(26)	42(23)	18(11)	6(4)	1(1)

1/ Figures in parentheses refer to number of poles containing that type of damage.

Table 9.--Woodpecker damage on coated Cellon and laminated poles after 30 months' exposure

Treatment	Blocks 1	2	3	4	5	6	7	8	9	Totals	No. poles damaged
	Damage index[1]										
Polyester	0	0	0	0	10	17	20	0	0	47	3 of 9
Koppers' 200	6	1	23	35	11	35	10	4	0	125	8 of 9
Baker's EC-167	0	0	7	0	8	20	19	0	0	54	4 of 9
BFG 0500	0	17	43	24	30	42	36	4	0	196	7 of 9
BFG 7802	23	18	37	5	10	25	35	0	8	161	8 of 9
Fiberglass	0	17	8	16	0	0	0	0	0	41	3 of 9
Wey-fil	0	4	0	7	3	0	10	0	0	24	4 of 9
Control	6	14	14	16	4	0	26	1	22	103	8 of 9
Laminate	[2]0	7	3	[2]1	[2]6	[2]0	--	--	--	17	4 of 6
Total	35	78	135	104	82	139	156	9	30	768	49 of 78

[1] Sum of all damage values.

[2] Sawed down and removed by vandals; damage from previous observation is entered.

Originally, there were six laminated poles included in the experiment. Four of those were cut down and removed by vandals after about one year's exposure. Before they were taken, one pole had a completed cavity excavated by Pileateds; another had minor damage. Of the two left in test, one had a hole 2.5 inches in diameter plus minor damage and the other had minor damage. Although this is a small sample involving laminated material, it appears that laminated poles are not immune to woodpecker attack.

In addition to the aforementioned wrapping materials a proprietary product, Vaughn Bar-Bird Pole Shields, was also tested in central Louisiana over a 2-year period (Rumsey 1972). The wrap was completely effective through two nesting seasons, even though most of the poles were being used by woodpeckers before they were wrapped. Conversely, over half the poles used as controls in the area were damaged.

The cost of Vaughn Shields is comparable to hardware cloth, about $35 to $50 per pole. Two men are required to wrap a standing pole; the climbers pass the coiled wrap back and forth as it is unwound spirally downward (Figure 19). The application of Vaughn wrap requires less time than when wrapping with hardware cloth. Also, linemen have indicated a preference for working with the plastic material. The durability has not been proved but the manufacturer anticipates at least a 20-year service life.

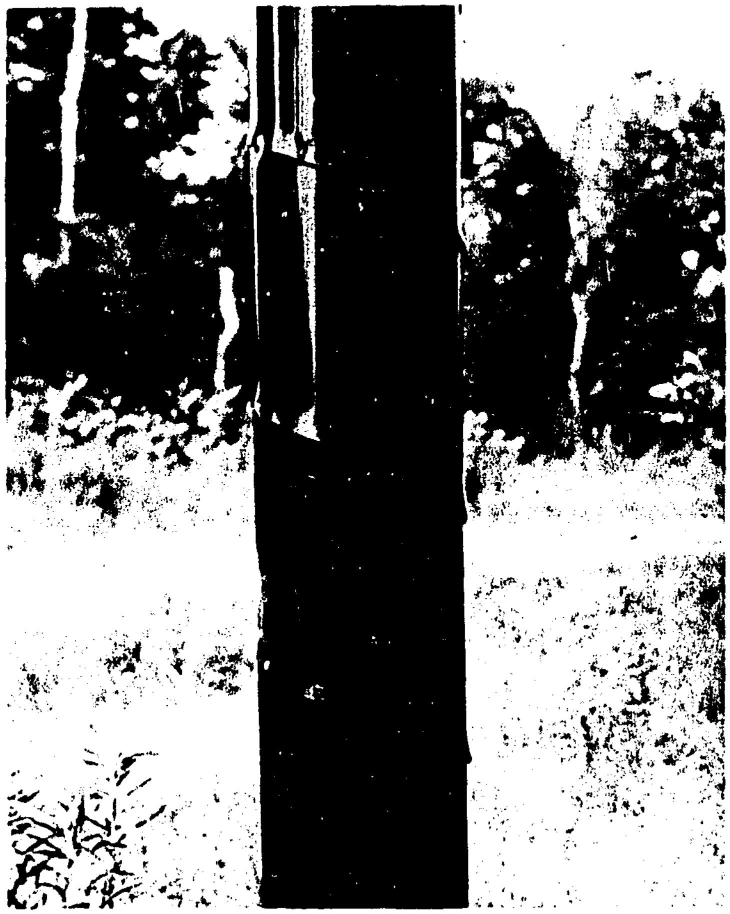


Figure 19. The overlapped windings of Vaughn Bar-Bird Pole Shields evidently prevent woodpeckers from gaining a perch.

Conclusions.--Several conclusions can be made regarding these tests. First, a factor already mentioned briefly, sound poles (that is poles without shakes) are damaged as much or more than poles with shakes. However, birds are attracted initially to shakes when shakes are present. Second, decoys on poles will be used by birds but the poles supporting decoys are damaged also. Third, a coating is effective as long as it is smooth. Wood poles, since they are wood and round also, are difficult media on which to apply and retain smooth, hard coatings. Fourth, wrappings are effective, but as with coatings, durability can be a problem. Vaughn Bar-Bird Pole Shields, a proprietary product, were completely effective in preventing woodpecker attack for the two years they were in test. The durability of the shields was not proven.

Laminated Poles

Because round poles are so difficult to coat or wrap, and because laminated poles are now being used in the industry, certain tests were conducted with laminated material. Since laminated poles are quite expensive, and I had the facilities for making laminated pieces 8.3 feet long, I used 8-foot sections mounted on top of round poles. The poles supporting the sections were wrapped with hardware cloth to prevent bird attack (Figure 20).

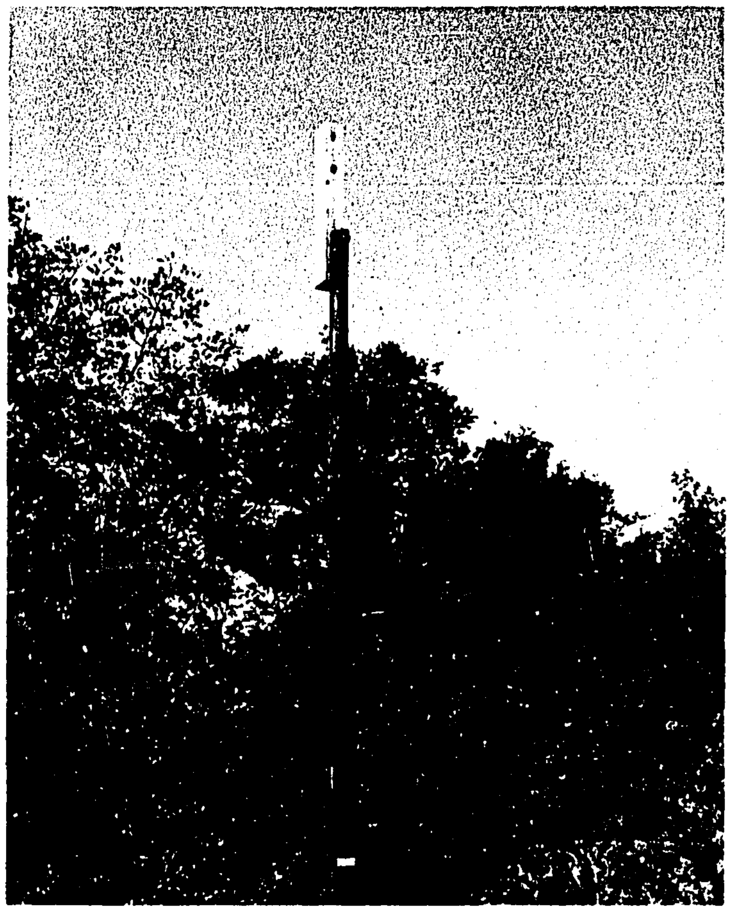


Figure 20. 12- x 12-inch laminated section mounted atop wrapped utility pole. (Saline Wildlife Management Area, LaSalle Parish, Louisiana, 1970.)

Procedures.--There were seven different treatments on the sections and three treatments using round poles. A detailed description of all treatments follows:

1. Eight-foot laminated sections constructed from five 2- x 8-inch southern pine boards overlaid with Weyerhaeuser's Wey-fil and with small stones embedded. Koppers' Penacolite Adhesive GO 4411 was used for gluing the boards.

2. Eight-foot laminated sections, approximately 7.5 inches square, overlaid with vulcanized fiber. Vulcanized fiber is a tough, lightweight, resilient, hornlike plastic material made by partial gelatination of the cellulose in paper, usually by the use of zinc chloride. A number of these layers were put together to produce the desired thickness. For this study, gray, 0.010 inch thick material was purchased from National Vulcanized Fibre Company, Wilmington, Delaware.

3. Eight-foot laminated sections, approximately 7.5 inches square overlaid with clear, 0.006 inch thick acrylic polymer in film form. This material is applied commercially to plywood, hardboard, particle board, etc. It was purchased as Korad A from Rohm and Haas Co., Philadelphia, Pa.

4. Eight-foot sections, approximately 7.5 inches square, laminated from dense, plain-sawed lumber. Dense grades of southern pine must average at least 6 rings per inch and must be at least one-third summerwood, or at least 4 rings per inch and at least one-half summerwood (Southern Pine Inspection Bureau 1970). Plain-sawed (flat-grain) lumber is sawed so that the growth rings form an angle of less than 45° with the widest surface of the piece.

5. Eight-foot sections, approximately 12 inches square, laminated from dense, plain-sawed southern pine lumber.

6. Eight-foot laminated sections, approximately 7.5 inches square, with 0.05 inch thick aluminum sheet embedded 0.75 inch beneath the surface. The sections were made from southern pine.

7. Eight-foot laminated southern pine sections, approximately 7.5 inches square, impregnated with phenol formaldehyde (Compreg, Borden Chemical Co.). Curing of the resin increases the density of the section.

8. Round poles of dense south Florida slash pine (*Pinus elliottii* var. *densa* Little and Dorman). They were approximately class 5 in size and about 30 feet long.

9. Round Chemonite Douglas-fir poles, approximately class 5, 30-foot, from the West Coast (California or Oregon). The process involves a water-borne preservative of ammoniacal copper arsenite (ACA). The poles were somewhat greenish in color and were reported to be fairly immune to woodpecker damage because the chemical makes the wood harder.

10. Round creosoted class 5, 30-foot southern pine poles used for controls.

With the exception of treatment number 5 listed above, the laminated sections were approximately 7.5 inches square. The 12-inch square treatment was used to prevent birds from spanning one face with their claws, since I had observed that woodpeckers could hang on upright, smooth surfaces by reaching two corners of a rectangular piece.

Treatments were replicated eight times in a randomized block design, except only six replications were used with south Florida slash pine poles. All poles were spaced approximately two-tenths of a mile apart along existing roads and fence rights-of-way in Saline Wildlife Management Area. Each pole was numbered with a plastic tag about 6 feet above ground line. The tag contained the consecutive pole number, the block number, and the location within the block. For instance, $\frac{24}{3-6}$ refers to pole 24, the third block, and the sixth pole within the block. A damage index based on the scheme described previously was obtained for each pole. When more than one kind of damage was present, a total was calculated for that pole.

The location and treatment of each pole is shown in Table 21, page 136.

Results and discussion.--The laminated sections mounted on round poles were in test for 20 months. During that time 47 of the 78 experimental units were damaged by woodpeckers (Table 10). Although there was a significant difference in the amount of damage between the treatments, it is academic whether the differences were real or chance--only Weyerhaeuser's Wey-fil epoxy with embedded rocks was completely effective. In contrast, all of the 12-inch square sections were attacked; six of the eight had damage in the three most severe categories (holes 1 inch or more inward, to completed cavities). Sections coated with Wey-fil and rocks should have provided good perches, but apparently the coating was sufficiently hard to deter the birds. Perhaps they perceived an irritating sensation through their bills or feet from the rocks.

The size of the 12-inch sections might have made them more attractive than the smaller sections to Pileated Woodpeckers. The purpose of incorporating the larger-sized sections into the experiment was to prevent woodpeckers from spanning two edges with their claws to have a secure perch when pecking and excavating. Either the 12-inch distance was not sufficient, or woodpeckers were able in some manner to cling to the flat surface. The latter seems the most likely, since several weather checks were noted that were large enough to enable birds to hang by their claws. After a perch was established, the woodpecker could in a stroke or two mar the surface of the section so that a more substantial perch would be available for greater excavation.

Table 10. Woodpecker damage to laminated sections and round poles

Treatments	Number of poles and sections with damage	Number of poles and sections with only severe damage[1/]	Total value of all damage[2/]
Epoxy and rocks	0	0	0
Dense boards	7	6	58
Phenol formaldehyde	4	2	17
Chemonite	4	3	48
12-inch square	8	6	50
Vulcanized fiber	6	5	35
Acrylic	3	1	16
Aluminum embedded	6	6	[3/] 24
South Fla. slash pine	5	5	56
Control	4	3	54
Total	47	37	358

1/ Severe damage includes categories 4, 5, and 6.

2/ Sum of all categories of damage.

3/ Birds could not penetrate metal so no damage greater than category 4 was found.

None of the treatments testing hardness were effective. The round Chemonite and south Florida slash pine poles, the sections impregnated with phenol formaldehyde, and the dense board laminates were damaged as much or more than the control.

The two treatments with smooth overlays--acrylic and vulcanized fiber--were also damaged, the latter more extensively than acrylic. It is difficult to imagine how the birds were able to gain a toehold on either of these coatings, initially. Observations with binoculars failed to reveal any splitting or failing of the coatings in the vicinity of woodpecker damage. However, the birds could have removed the evidence through their excavating.

Woodpeckers removed large patches of wood overlaying the aluminum but were not able to penetrate the metal. On some poles 2 to 3 square feet of wood were chipped away down to the metal. Apparently the birds were attempting to peck around the edge of the metal. In one such instance they chipped away an area of wood 5 x 36 inches to the depth of the metal.

The epoxy and rock treatment was included in the experiment mainly to test the principle of an overlay and not the material *per se*. Wey-fil epoxy itself would likely be prohibitive in cost, even if all difficulties of its application could be overcome.

Conclusions.--Some of the conclusions of this test further support those obtained in other tests, namely that laminated material is not immune to woodpecker attack and that there is not a natural hardness sufficient to thwart woodpeckers in species of timber used for poles.

Nor are the salts treatments likely to provide poles too hard for woodpeckers to damage. Rocks embedded in Wey-fil gave a completely effective coating but the practicality of that material is doubtful. However, the test indicates that a hard coating can be effective.

Chemicals

An ideal solution to the woodpecker problem would be the addition of a cheap, easy to handle chemical repellent into the preservative treatment. Several chemicals were given preliminary screening in the aviary and in the field.

Procedures.--In most cases the material was applied to areas on poles currently being worked by woodpeckers; an interruption of activity by the bird indicated an effective repellent. In other instances the test material was placed in completed cavities, or on pole sections and fence posts before any attack had begun. The expense and inefficaciousness of most chemicals dictated exploratory testing on a small scale. Following is a list of the main chemicals and chemical compounds used in tests. Not included are various mixtures, concentrations, and carriers.

p-Benzoquinone
Arasan
Olive green-B
Thiram Animal Repellent
Sodium silicofluoride
Naphthalene
Methylhydroquinone
Phillips Petroleum Company's R-12, R-2363, and R-2953
Dimethylsulfoxide
Rosin--light, dark, powdered, flaked, and liquid
Roost-No-More
B. F. Goodrich's NP-2
Cedarwood oil
Copper naphthanate
Pliogrip (liquid rubber)
Minnesota Mining and Manufacturing Company's EC-244, EC-226, and Coro-Gard 1706

Results and discussion.--The use of chemicals was one of the least promising approaches in all tests. Chemicals that were known to be effective against various species of birds had no effect on woodpeckers. Thiram (tetramethylthiuramdisulfide), for instance, which is used as a bird repellent on pine seed (Derr and Mann 1971), was removed from several spots being worked by woodpeckers as soon as technicians moved away from the poles. The products from Phillips Petroleum Company seemed to provide some degree of success when mixed with cement and used as hole fillers. It was later determined that the cement itself provided the same degree of protection after it hardened, while the chemicals gave no protection when applied directly to places being worked by woodpeckers. Another example of apparent success was obtained with p-benzoquinone in a grease carrier, but as soon as the grease was no longer tacky there was no repellency. Grease itself was effective until it hardened, soaked in, or was washed away. Any material that adhered to the birds' feathers or feet caused avoidance, and prolonged periods of grooming followed such contact. Lethal chemicals might be available, but if the impracticability of using them against birds is not enough, it should be remembered that many poles are climbed by linemen and also that many poles are placed over cropland or pastureland. With the recent interest in environmental pollution, use of chemical repellents is likely to come under closer scrutiny by environmental protection agencies. Nonselective chemicals especially will have to function only as repellents and not lethal agents. Any added restrictions are likely to make it even less hopeful that a chemical solution to the woodpecker problem is possible.

Conclusions.--The solution to the woodpecker problem does not likely include the use of chemicals. Numerous factors mentioned and implied lead me to that conclusion.

Repairing damage

Some utility companies fill or repair woodpecker excavations in poles without giving consideration to the long-range effectiveness of this practice. For example, do woodpeckers return to repaired poles and excavate new cavities? Or will they excavate several smaller holes in an attempt to get back into their old cavities? Finally, if woodpeckers are permitted to keep their old cavities will they continue to damage the pole? The following test was undertaken to provide answers to these questions.

Procedures.--A randomized block design with eight blocks and two treatments was used. Each block contained 10 creosoted utility poles: five in which all woodpecker holes were filled with rock-hard putty and five in which the holes were left unfilled. However, damage measurements were recorded from only the three inside poles in each plot; the outer two were used as buffers to minimize any border effect. Therefore, data were collected from 48 poles: 30 in a distribution line in Saline Wildlife Management Area and 18 in a distribution line in Bayou Boeuf swamp near Alexandria, Louisiana.

Results and discussion.--Poles with woodpecker holes filled and poles with holes left unfilled were observed closely through three nesting seasons. Sixteen of the 24 poles in each treatment were damaged (Table 11). The only apparent numerical difference in any category of damage was in the 1 inch holes--35 in filled poles and only 11 in unfilled. This indicates a stronger tendency for exploratory pecking after existing holes are filled. Damage greater than 1 inch was almost the same in the two treatments, 30 and 28 instances.

The analysis of variance, using values based on severity of damage, revealed no significant difference between the two treatments (Table 22, p.140). Completed cavities, the most serious type of damage, were somewhat more numerous in filled poles than unfilled, but two existing cavities in unfilled poles also were deepened and used in successive years.

Not only did this study illustrate that hole filling had little or no effect in increasing or decreasing woodpecker attack, but it was also apparent that damage was still occurring at a relatively high rate. Most of the poles were treated in May 1964, and probably set within a few months after that. Consequently, at least 7 years lapsed. At the beginning of the woodpecker research there was a theory that woodpeckers attacked poles only for the first few years after a line was built. After that time the birds supposedly had a sufficient number of holes or the poles became too hard through weathering. Therefore, it was felt that a suitable deterrent, or preventive, need be effective for only a few years. Apparently that is not the case.

Table 11. Number and severity of woodpecker attacks on poles with holes filled and with holes unfilled

	Holes filled						Holes unfilled					
		Number of holes						Number of holes				
Block	Pole no.	1 inch	2 inch	3 inch	Completed cavity	Peck work	Pole no.	1 inch	2 inch	3 inch	Completed cavity	Peck work
					Poles in test for 40 months							
I	11	1/ -	-	-	-	-	4	-	-	1	1	-
	12	3	1	-	-	-	5	-	-	1	1	-
	13	-	1	-	-	-	6	-	-	-	-	Yes
II	31	2	1	1	1	-	21	-	-	-	-	-
	32	5	-	-	1	-	22	-	2	-	-	Yes
	33	12	-	1	1	-	23	2	-	-	2/ -	Yes
III	41	-	-	-	-	-	47	-	1	1	-	-
	42	-	-	-	-	Yes	48	-	1	-	2/ -	-
	43	2	-	1	-	Yes	49	-	-	1	-	Yes
IV	71	-	2	-	-	Yes	62	2	2	-	-	-
	72	-	-	-	-	-	63	-	2	-	-	-
	73	3	-	-	-	Yes	64	-	-	-	-	-
V	86	-	-	-	-	-	76	1	2	-	-	-
	87	-	-	-	-	-	77	-	-	-	-	-
	88	-	-	-	-	-	78	3	4	-	-	Yes
					Poles in test for 30 months							
VI	10B	3	2	-	1	Yes	5B	1	-	-	-	Yes
	11B	-	1	4	-	Yes	6B	-	-	-	-	-
	12B	1	-	2	1	Yes	7B	-	-	-	-	-
VII	21B	-	-	-	-	Yes	16B	-	-	-	-	-
	22B	1	-	-	-	Yes	17B	-	-	-	1	-
	23B	1	-	1	-	Yes	18B	-	-	-	-	Yes
VIII	26B	1	1	1	-	-	31B	1	1	1	1	-
	27B	-	-	1	-	-	32B	1	1	1	-	Yes
	28B	1	2	-	2	Yes	33B	-	-	2	-	-
Total		35	11	12	7	11		11	16	8	4	8

1/ Dash indicates none.

2/ Cavity present when study initiated but was deepened.

Two of the utility companies that financed the woodpecker research can also offer first-hand accounts of unpleasant experiences with hole-filling practices. Mr. R. Odum, line inspector for Public Service Company of Oklahoma, recently stated that filling holes in spring and summer caused more damage because birds attempted to drill into their old cavities. He believed that holes should be filled in the fall and winter. However, in the present study, in which holes were filled in January and November, damage occurred in the fall and winter also.

Louisiana Power and Light Company recently spent several thousand dollars filling woodpecker holes in a line near Marksville, Louisiana. The poles were not wrapped with hardware cloth, and within a few months the line was again seriously damaged by woodpeckers.

Conclusions.--Whether or not woodpecker damage is repaired, there is little effect on the amount of damage that follows. However, there is apparently a tendency for woodpeckers to make more small, exploratory probes in poles after all previously excavated holes are filled. Such holes, if not enlarged, would not require any remedial action. Another finding of interest is that poles are still being damaged at a relatively high rate after 7 years, which discounts the belief that damage drops off sharply after an initial peak soon after construction of the line. If the rate does decrease, it is still far above an acceptable level.

Evaluating damage

Woodpecker damage may have two serious effects on poles: a reduction in strength or an opening for decay organisms. Both were investigated in this research.

Strength Loss

Procedures.--Eighteen class 2, 50-foot creosoted southern pine poles were experimentally broken in the field in an effort to determine the extent that woodpecker damage reduces strength. All poles were on Saline Wildlife Management Area and, with the exception of two used as controls, contained one or more completed nest cavities or holes with openings at least 3 inches in diameter. A cable was attached 2 feet down from the top of the poles (ASTM Standard D1036-58) and force was applied with a winch truck. Force was applied in a direction so that the side of a pole with the greatest amount of wood loss was in tension. This permitted standardization, and it was presumed that poles would fail easier with the damage in tension than compression. The rate of loading was about 7.5 feet per minute. A dynamometer was placed in the line to record the amount of force necessary to break the poles. Poles with more than one cavity were tested in a direction that was presumed to result in the breakage with the least force. A special collar was built to place around the poles at the ground to restrain them from pulling over. The collar was not used on the first pole and, although it had a completed cavity, it caved over instead of breaking.

Circumferential measurements were made at the top, point of loading, groundline, and point of failure. The length of pole above groundline and distance from top to point of failure were also measured. All woodpecker holes in each pole were plotted on a data sheet and their dimensions described. Later, a calculation was made of the amount of wood removed in cross-sectional area at the holes (Figure 21). However, wood excavated was determined for only one cross-sectional plane for inclusion in the results. In other words, damage at different levels was not added.

A mathematical model was constructed to predict strength loss based on changes in moments of inertia due to removal of wood. Values obtained from poles in the field were used to test the model.

<u>Results and discussion</u>.--Twelve of the damaged poles failed at woodpecker holes; the other four failed nearer the ground. One badly damaged pole caved over before the groundline restraining collar was put into use (the poles were approximately 7 feet in the ground). None of the poles had been in the field over 4 years, and all were free of decay.

Important findings of the test are summarized in Table 12. The percent of cross-sectional area of wood removed at woodpecker holes (column 5 in Table 12) ranged from 12.3 to 72.2 percent with an average of 39.5 percent. The average horizontal distance of the openings was 3.5 inches, or about 8 percent of the average circumference. When cut horizontally through the openings, the cavities were somewhat U-shaped, especially the completed nest cavities.

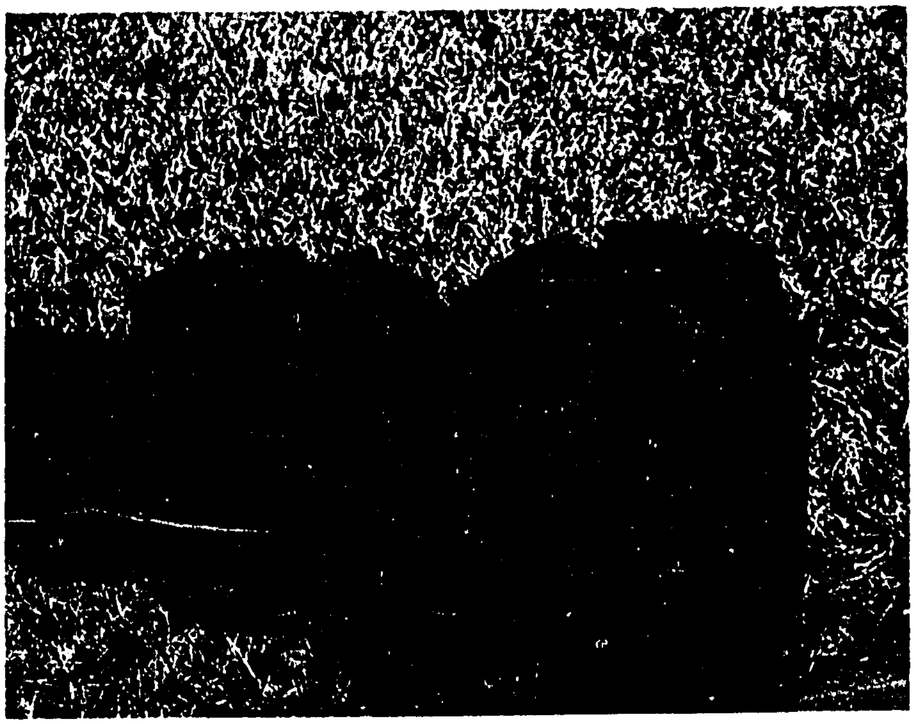


Figure 21. Pole section showing cross-sectional configuration of a horizontal cut through the center of the cavity entrance.

Table 12. Data obtained from breaking 18 woodpecker-damaged utility poles

Pole number	Distance apex to ground	Distance apex to point of failure	Diameter at point of failure	Wood removed from x-sect. area at point of most severe damage	F_x, lateral force necessary to break poles	NESC rating at point of failure	Proportion of strength compared to rated value
	-------Feet-------		Inches	Percent	Pounds	Foot-lbs.	Percent
1221	44.2	19.5	11.6	32.0	2,152	72,698	51.8
2112	42.2	39.2	14.0	12.3	4,826	136,580	131.4
2122	41.7	9.7	11.8	52.0	4,257	50,155	65.4
2211	43.4	31.4	12.4	45.2	3,641	108,076	99.0
2212	43.1	38.8	13.4	0	3,704	135,009	101.0
2221	43.1	23.5	12.8	30.5	4,077	83,557	104.9
2222	43.6	18.8	11.5	52.9	4,184	70,391	99.9
4112	43.0	33.2	14.0	24.5	4,521	114,260	123.5
4121	42.6	3.8	9.1	72.2	2,465	39,145	11.3
4211	42.4	28.6	12.1	0	3,512	98,803	94.6
4221	43.1	17.3	11.9	44.3	2,467	67,146	56.0
5112	43.7	36.0	13.8	19.7	4,208	124,340	115.1
5121	43.2	39.8	13.4	17.2	4,173	132,869	120.1
6121	43.2	27.0	12.7	25.5	2,161	93,894	57.5
6222	42.2	18.8	11.5	54.2	3,784	70,897	91.8
7122	42.9	5.2	10.3	62.7	4,403	41,684	34.3
7221	43.1	18.0	11.3	45.6	2,467	88,181	64.5
7222	44.1	15.3	11.1	41.8	3,089	62,353	65.9

Cavities extended inward toward the cores of the poles an average of 8.7 inches. Since the average diameter of the poles at completed cavities was 11.6 inches, about 3 inches of wood remained at the back. The thickness of wood at the back side of holes is usually greater than on the sides of the cavities, where the remaining wood may be less than 1 inch thick. The diameters at point of failure (column 4) averaged 12.2 inches.

All the poles were 50 feet in length with about 7 feet in the ground, so 43 feet were above groundline (column 2). Damaged poles that broke at woodpecker holes averaged 17.7 feet from the apex to the point of failure (column 3). The two poles that had no damage and the four that did not break at woodpecker holes averaged 35.1 feet from the apex to point of failure. This is in agreement with results from Wood et al. (1960) at the Forest Products Laboratory, Madison, Wisconsin, who found that 55-foot untreated southern pine poles tested by the cantilever method broke at 9.0 feet above the groundline. They also found that smaller poles (25 and 30 feet) broke nearer the ground, the majority from 1 to 3 feet above groundline. They stated that the difference between the large and small poles was due to the maximum stress in a cantilever with the shape of a frustum occurring where the diameter is 1.5 times the diameter at point of loading. Since the taper is greater in larger poles, the point of maximum stress was higher from the groundline than for the shorter poles.

The amount of force necessary to break the test poles was compared to National Electric Safety Code values computed in the REA Line Manual Bulletin 66-1 (columns 6, 7, and 8). Those values represent the resisting moments for specified sizes of poles at 1-foot increments from the apex. The two poles without holes averaged 97.8 percent of the expected rating. The four that did not break at woodpecker holes averaged 118.5 percent. Essentially these functioned as controls, but not completely. They probably represent the stronger poles of the population.

The relationship between distance from the ground to the point of failure, the amount of wood removed in cross-sectional area, and the percent of rated strength remaining at failure are shown in Figure 22. Since the sample was small ($n = 18$) and the woodpecker damage not of a predetermined size or height, correlations between the variables--amount of wood removed, distance from the ground to point of failure, and amount of strength left in the poles--are difficult to determine. However, certain conclusions can be made based on the data and information in the literature.

Damage near the top of a pole does not weaken it as much as when it is nearer the point of maximum stress, which is a few feet up from the groundline. For the four poles that broke below the woodpecker holes, the distances above groundline to points of failure were 3.0, 12.0, 9.8, and 3.4 feet, averaging 7.05 feet. All four of these poles had severe woodpecker damage. Pole #5121 had 17.2 percent of its cross-sectional area removed at 21.1 feet above groundline, pole 2112 had 12.3 percent at 25.8 feet, pole 4112 had 24.5 percent removed at 31.3 feet, and pole 2211 had 45.2 percent removed at 35.2 feet. And yet these four poles broke below the point of damage with an average force of 118.5 percent of the rating required to cause failure.

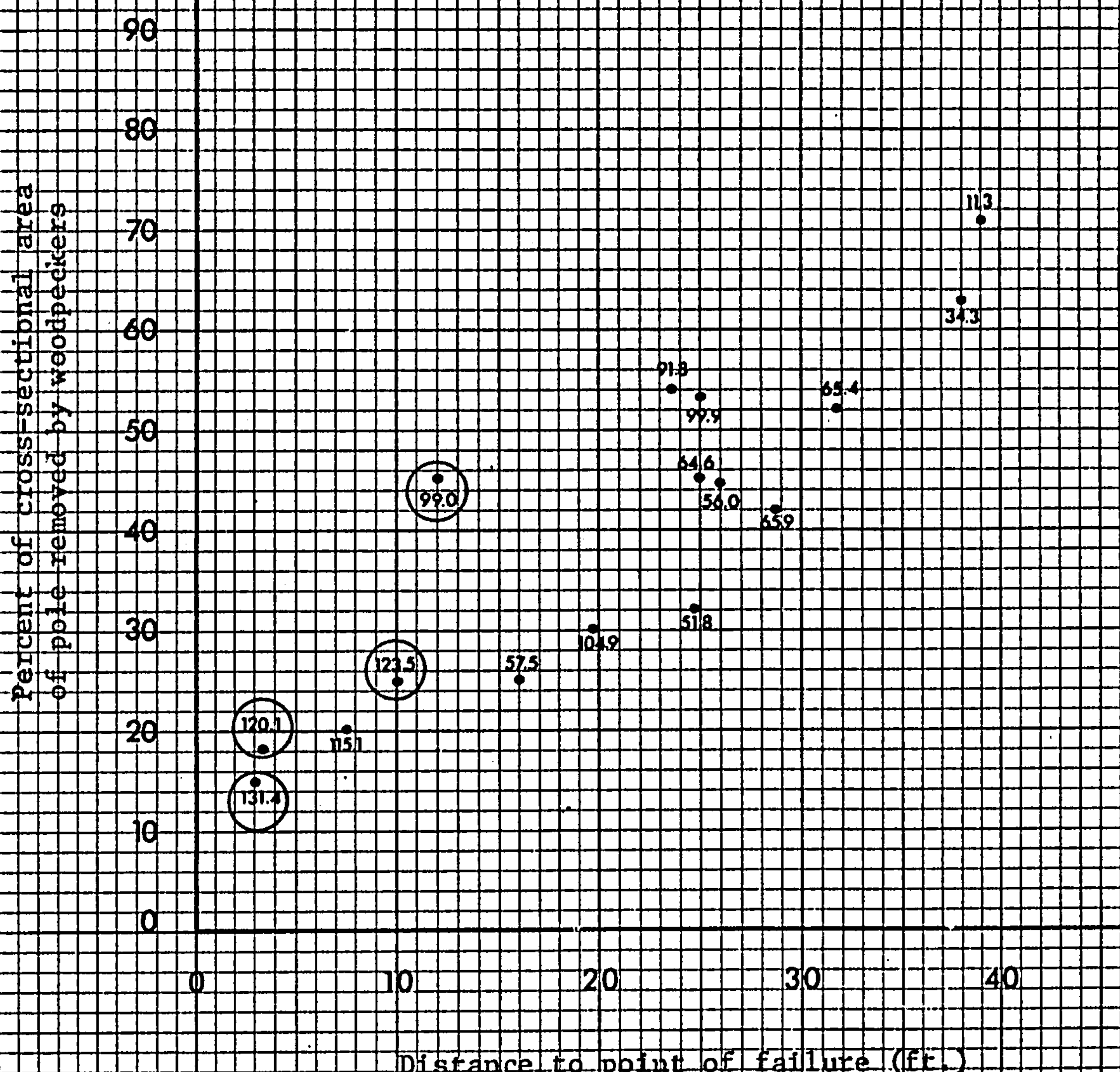


Figure 22. The relationship between percent of wood removed, distance to point of failure, and percent of strength remaining (based on NESC rating) in woodpecker damaged poles. Percent of rated strength at failure is ratio of applied force to NESC rating; these values are shown beside each plotted point. Poles with circles failed below woodpecker damage.

The two poles that broke with the least amount of force also had the largest amount of cross-sectional area removed. Pole 4121, with 72.2 percent of the wood removed, retained only 11.3 percent of its strength; pole 7122 had 62.7 percent wood removed and retained 34.3 percent of its strength. The configuration or shape of the woodpecker damage, hence the shape of the wood remaining, affects the strength. For instance, it is possible that the 27.8 percent of the wood remaining on pole 4121 would have caused a different strength value if the excavation around the center of the pole had a different distribution. The configuration causing the least reduction in strength would be a small opening with most of the wood removed from the center of the pole. This would resemble a hollow pipe with most of the circumference intact.

As seen in this study, and supported by other studies, there is considerable variation in the strength of wooden poles. By definition, the southern pines include several species which probably differ in strength. But based on hundreds or thousands of poles these differences might not be important. Also, as much or more variation can be expected within a species as between species. While little if anything can be done about this natural variation, the practices of wood conditioning and preservation can be manipulated.

W. S. Thompson (1969) of the Forest Products Utilization Laboratory at Mississippi State University has published research results dealing with the effects of steaming and kiln drying on the properties of southern pine poles. He found that kiln-dried poles had higher strength values than poles steamed according to current standards. The temperature

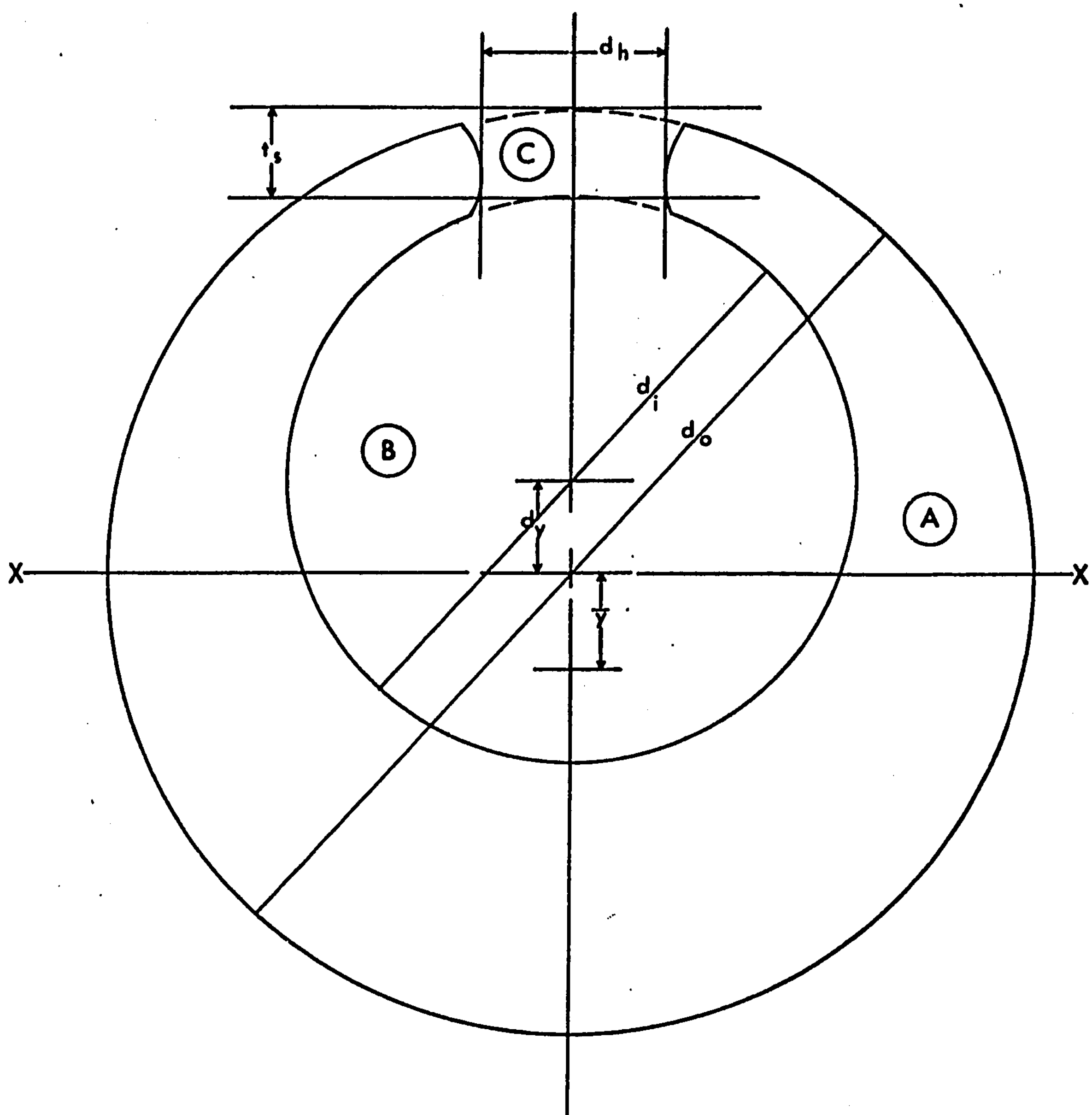
of drying also affected strength but not drastically. One possible drawback of kiln drying is the effect on retention of creosote. Thompson found that poles that had been dried at 182° F contained significantly less preservative than those dried at 152° F, but a supplementary study did not support this. He concluded that further work is needed.

It is probable that if treating companies have excessive difficulty in treating kiln-dried poles, even though strength properties are higher, they would be reluctant to discard steaming in favor of kiln drying. Penetration and retention of preservative are two of the most important requirements with which treaters are concerned.

Another controllable factor affecting strength of finished poles is machine peeling. While this process results in making poles esthetically pleasing, it can also result in a loss of strength when crooks and enlarged portions are removed. Consequently, until recently many utility companies required their large poles to be hand-peeled, but lately most have been forced to use machine-peeled poles.

In connection with the field results, an attempt was made to construct a mathematical model that could be used in estimating lateral load-carrying capacity in woodpecker-damaged poles. The necessary assumptions are:

1. The pole is fixed in the ground and acts as a cantilever with a tapered section.
2. The cross section is homogeneous.
3. Lateral load is applied 2 feet below the apex of the pole.
4. The woodpecker nest cavity is approximated with a circle (area B in Figure 23) and a rectangle (area C, Figure 23).
5. The damage is assumed to be in the worst position around the circumference of the pole, i.e. consider it with most respect to the x-x axis (Figure 23).



d_o = outside diameter, inches
d_i = inside diameter, inches
t_s = thickness of shell at entrance, inches
d_h = horizontal opening of entrance, inches
d_y = distance from original centroid to centroid of area B, inches
$\bar{y}$ = displacement of centroid, inches

Figure 23. Model used for calculating reduction of moment of inertia in a damaged pole.

The procedure which follows assumes that the damage reduces the moment of inertia of the pole and shifts the centroidal axis away from the center (Popov 1968). As an example, suppose a class 2, 50-foot pole contains woodpecker damage 23.5 feet from the apex. Measurements are (refer to Figure 23 for clarification):

d_o = outside diameter of pole = 12.8 inches

d_i = inside diameter of cavity = 6.6 inches

d_h = horizontal width of entrance = 3.25 inches

t_s = average thickness of shell on each side of entrance hole = 1.8 inches

The following calculations are then made.

1. Cross-sectional areas.
2. Location of centroid after damage.
3. New moment of inertia after damage.

Calculation of areas:

A = Area of cross-section of pole without damage = $\dfrac{\pi (d_o)^2}{4}$ = 128.61 in.^{2}

B = Area inside cavity = $\dfrac{\pi (d_i)^2}{4}$ = 34.19 in.^{2}

C = Area of entrance $(d_h)(t_s)$ = 4.22 in.^{2}

Location of centroid:

(Col. 1) Area Inch^2	(Col. 2) Distance from center to centroid of area Inch	(Col. 1) x (Col. 2)
A = 128.61	0	0
B = -34.19	+1.3	-44.45
C = -4.22	+5.5	-23.21
+90.20		-67.66

$$\bar{y} = \frac{-67.66}{90.20} = -0.75 \text{ inches}$$

Thus, the centroid has shifted away from the center of the pole, that is, away from the entrance hole.

Calculation of moment of inertia of new section using parallel axis theorem (Popov 1968):

$$I = \bar{I} + Ad^2$$

therefore:

$I_o = \bar{I}_o \; Ad^2$ = Moment of inertia of original section about new controidal axis

$\bar{I}_o$ = Moment of inertia of original section about its own centroidal axis

d = Distance from new centroidal axis to centroid of area A

A = Area of original section

$$\bar{I}_o = \frac{\pi(d_o)^4}{64} = \frac{\pi(12.8)^4}{64} = 1316.94 \text{ in.}^4$$

$$Ad^2 = (128.61)(-.75)^2 = 72.34 \text{ in.}^4$$

$$\text{and} \quad I_o = 1389.28 \text{ in.}^4$$

similarly:

I_b = I of area B about new centroidal axis

$$\bar{I}_b \equiv \frac{\pi(d_i)^4}{64} = \frac{\pi(6.6)^4}{64} = 93.09$$

$$Bd_b^2 = (34.19)(2.05)^2 = \underline{143.68}$$

$$I_b = \quad = 236.77 \text{ in.}^4$$

and I_c = I of area C about new centroidal axis

$$\bar{I}_c = \frac{(d_h)(t_s)^3}{12} = \frac{(3.25)(1.8)^3}{12} = 1.58$$

$$Cd_c^2 = (4.22)(6.25)^2 = \underline{164.84}$$

$$I_c = 166.42 \text{ in.}^4$$

$$I_{composite} = I_o - I_b - I_c = 986.09 \text{ in.}^4$$

Estimated lateral load-carrying capacity:

An average value for fiber stress was obtained from the two undamaged poles and from four poles that broke below the woodpecker damage. Test results for these six poles ranged from 6,284 to 8,017 p.s.i. with an average of 7,091 p.s.i. Using the composite moment of inertia of the section at the location of damage, the location of the centroid, and the average maximum fiber stress, it is possible to solve for the estimated load from the equation:

$$P = \frac{\sigma I}{(12)(L)(c)}$$

where P = Estimated load to cause failure, pounds

σ = Average maximum fiber stress, p.s.i.

I = Moment of inertia after damage, in.^{4}

L = Distance from load point to damage, feet

c = Distance from centroidal axis to extreme fibers, inches.

Using values from the example, a P of 3,788 pounds was calculated. This compares to an actual load of 4,077 pounds. By using the preceding method, estimated loads were computed for the test poles and are compared with actual loads obtained in the field (Table 13).

Several points require elaboration. The average stress value calculated (7,091 p.s.i.) should actually not be applied to the upper portion of the poles because all the control poles failed in the region of maximum stress, which is in the lower portion of the pole. This portion is relatively free of knots and probably exhibits a different bending strength than the upper portion, especially when the upper part contains several knots. Also, it is recognized that strength may be reduced when knots are shaved too closely in machine peeling.

Consideration should be given to the location of woodpecker damage in relation to the region of maximum stress. Fiber stress increases up to the mid-point of the pole and slowly approaches a maximum at about 33 feet from the load point before declining. At mid-point approximately 90 percent of the stress has been developed. These calculations are based on the minimum dimensions of a 50-foot, class 2 pole which is set 7 feet in the ground and loaded as a cantilever at a point 2 feet below the apex. A uniform taper has been assumed from a top circumference of 25 inches to a minimum circumference of 42 inches at 6 feet from the butt (ASA 1963).

Table 13. Comparison of actual to estimated failure loads for woodpecker-damaged poles

Pole number	Conditioning	Reduction of section modulus	Percent wood removed Actual	Percent wood removed Model	Distance from load	Actual load	Est. load
		Pct. of original			Feet	---Pounds---	
1221	[2] S	38.5	32.0	31.2	17.5	2,152	3,179
2221	S	33.0	30.5	29.9	21.5	4,077	3,788
2222	S	45.3	52.9	42.8	16.8	4,184	2,843
2122	K	55.1	52.0	49.4	7.7	4,257	5,986
4121	K	62.8	72.2	66.4	1.8	2,465	9,033
4221	S	48.6	44.3	36.2	15.3	2,467	3,283
5112 [1]	K	--	11.6	--	34.0	4,208	3,069
6121	K	41.5	25.5	26.0	25.0	2,161	2,776
6222 [1]	S	--	54.2	--	16.8	3,784	2,848
7122	K	56.6	62.7	60.4	3.2	4,403	8,576
7221	S	46.3	45.6	42.2	16.0	2,467	2,806
7222	S	43.7	41.8	38.9	13.3	3,089	3,358

1/ These poles had more than one hole in horizontal plane of failure; probably should not be included.

2/ S denotes steam conditioning; K denotes kiln dried.

Conclusions.--The preceding comments emphasize various difficulties in making an estimate of the lateral load-carrying capacity of a damaged pole. One of the more important factors to be considered is the stress concentration occurring where the cross-section changes abruptly as at a woodpecker cavity. When such factors as variations in density, possible buckling, and natural variation of wood are added, it is not surprising that the estimated values calculated and shown in Table 13 have such a wide variation.

In order for the technique to be used as a means for the selective removal of damaged poles from a utility line, information is needed on stress concentrations at the location of woodpecker damage. Also needed are values of maximum bending strength for the upper portions of poles where woodpecker damage is likely to occur.

Decay

The fact that woodpeckers penetrate the outer protective layer of heavily preserved wood has led utility company engineers to believe decay in damaged poles is inevitable.

Procedures.--To obtain information on the preceding supposition, 80 creosoted pine pole sections were collected by the cooperating utility companies for examination. The presence or absence of decay and conditions in the pole which may have led to initial attack were noted.

A test to evaluate further the rate and seriousness of decay in creosoted sections was conducted in a greenhouse. Twenty-four creosoted sections 8 to 12 inches in diameter and approximately 24 inches long were modified to resemble woodpecker damage. Cuplike depressions were chiseled out of one end of each section (Figure 24). On 12 sections a mixture of pentachlorophenol and oil was added at the rate of 0.5 pound of dry penta salts per cubic foot, based on the calculated volume of wood in the cylinder directly below the depression (denoted by arrow). Then two levels of water, 50 ml and 100 ml, were added to the 24 sections at weekly intervals

The treatments were:

1. 6 sections--50 ml of water added once a week (Sections 303, 305, 309, 313, 317, and 319).
2. 6 sections--100 ml of water added once a week (Sections 302, 307, 310, 314, 315, and 318).
3. 6 sections--50 ml of water added once a week but treated with pentachlorophenol prior to addition of the first water (Sections 306, 311, 312, 322, 323, and 324).
4. 6 sections--100 ml of water added once a week but treated with pentachlorophenol prior to addition of the first water (Sections 301, 304, 308, 316, 320, and 321).

All sections were placed in a greenhouse where it was believed the warmer temperatures inside would accelerate the rate of decay. The study was started in April 1969. In August 1971 the sections were split and cultures for fungi were made from chips taken near the bottom and sides of the excavations. Three plates, each with five chips for a total of 15 samples, were made for each section. In addition, a completed nest cavity was collected from the field and wood samples were taken from 55 spots close to where the wood was removed.

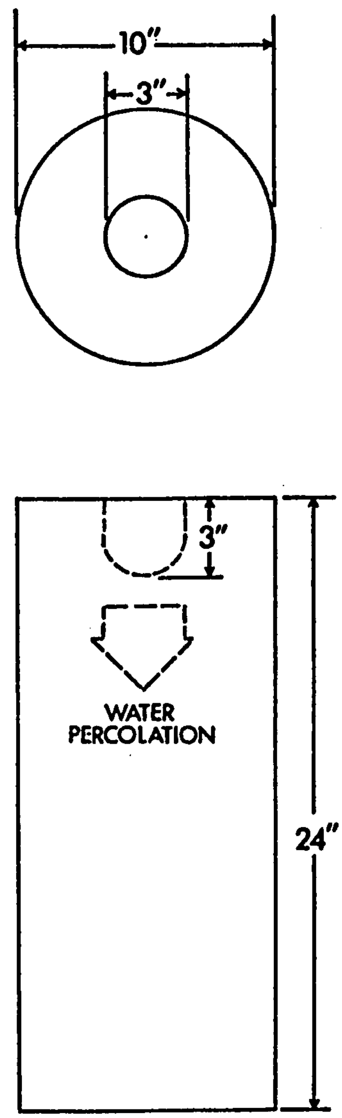


Figure 24. Cuplike depressions were chiseled out of creosoted sections and water added at weekly intervals to encourage decay.

Since all sections were not the same diameter, the penetration of creosote was not comparable. To permit isolation of variation caused by this, the sections were blocked for statistical analysis; within each block the sections were as uniform in size as possible. Treatments were assigned at random to sections within the blocks. There were six blocks and four treatments in the study. The frequency of decay was the test variable.

Results and discussion.--In examining 80 sections of damaged poles collected by the cooperators in Louisiana, south Arkansas, and east Texas, I found only two in which decay was definitely associated with woodpecker attack. Admittedly, woodpeckers deepen cavities they reuse and thereby remove evidence of decay. Many of the sections collected were from poles being changed out for reasons other than woodpecker damage, and from their appearance were several years old and almost certainly having some groundline decay.

Of the 24 sections maintained in test under conditions favoring decay, only section #307 had visible decay after 28 months. That section was not pretreated with pentachlorophenol and had 100 ml. of water added weekly. Dissection revealed the amount of preservative (creosote) was far below specifications. The outer 1/4 to 1/2 inch layer of wood was stained by the creosote, but inside wood was unstained. Failure to get deep penetration of the preservative happens occasionally in the treating cylinder, and it is customary to retreat those poles not passing specifications. Close inspection at the treating plant is needed to avoid selling poles with a substandard treatment.

To determine if fungi were present in the sections (although decay was not visible), pathologists from the U. S. Forest Service, Southeastern Area State and Private Forestry were asked for assistance. They prepared media and directed the procedure for making cultures. Fifteen samples were taken from each section. Also, 55 cultures were made from the wood remaining around and below the nest cavity collected in the field. A summary of the cultures is presented in Table 14.

A fungus of the genus *Amblyosporium* was found in 119 of the 360 samples, or 33 percent. That was the only fungus found consistently throughout the samples. Rarely, a bacterial colony or another fungus showed up as contaminants and were not localized to the wood chips. As stated earlier, with one exception, no decay was visible in the sections prior to culturing.

The analysis of variance for comparing the four treatments (Table 23, p. 141) revealed a significant difference between treatments ($P < .05$). Those sections given a pretreatment of penta had less fungi.

The sections obtained from the field contained a cavity excavated by Pileated Woodpeckers 17 months previously. There was no visible sign of decay, but two of the 55 cultures showed growths of *Amblyosporium* and five had a *Penicillium*-like fungus that was not further identified.

Amblyosporium and the other fungi found in this study probably do not cause wood decay. *Amblyosporium* is considered a soil fungus and has evidently not been studied extensively. The other fungi found seem to be fairly closely related to *Amblyosporium*, so they probably have similar habits. Possibly the fungi were relatively dormant in the test

Table 14. Frequency of fungi in wood-chip cultures

Section number	Treatment number 1/	Number of cultures with fungi	Percent of total (No. with fungi / 15)
303	1	7	47
305	1	7	47
309	1	8	53
313	1	7	47
317	1	14	93
319	1	10	67
302	2	1	7
307	2	15	100
310	2	4	27
314	2	7	47
315	2	4	27
318	2	0	0
306	3	2	13
311	3	0	0
312	3	3	20
322	3	11	73
323	3	2	13
324	3	8	53
301	4	0	0
304	4	0	0
308	4	1	7
316	4	1	7
320	4	0	0
321	4	7	47

1/See page 107.

sections and were prolific only on the laboratory media. Or, it is possible that there was sufficient preservative to hold them in check.

Conclusions.--The conclusions from this experiment will be included with those from the following section.

Measurements of Rainfall Entering Cavities

Procedures.--In conjunction with the decay work I was also interested in the amount of rainfall that actually entered a woodpecker cavity. Therefore, four sections each with a man-made woodpecker nest cavity were mounted near the top of a 30-foot pole (Figure 25). The openings of the cavities were oriented in azimuths of 83°, 173°, 263°, and 353°. Plastic bags were placed in the cavities to catch the water that blew in. A bulb and siphon tube were used to remove the water, which was measured in a graduated cylinder. A standard rain gauge was used to measure total rainfall. This permitted comparison between the amount of rain that entered the cavities and the amount that fell.

Results and discussion.--The amount of rainfall that entered the four cavities in 14 separate rainstorms, over a 4-month period from December 1968 through March 1969, was measured (Table 15). Amounts varied widely, depending on the aspect of the openings. Cavities facing 173° and 263° received the highest percentages of rainfall with over 70 percent of the total in three storms. During each of the 14 rainstorms, measurable amounts were caught in the south-facing cavity. There were only two instances when measurable amounts were not caught in the west cavity. The east-facing cavity with an azimuth of 83° received essentially no rain, and the one facing 353° (north) received token amounts.

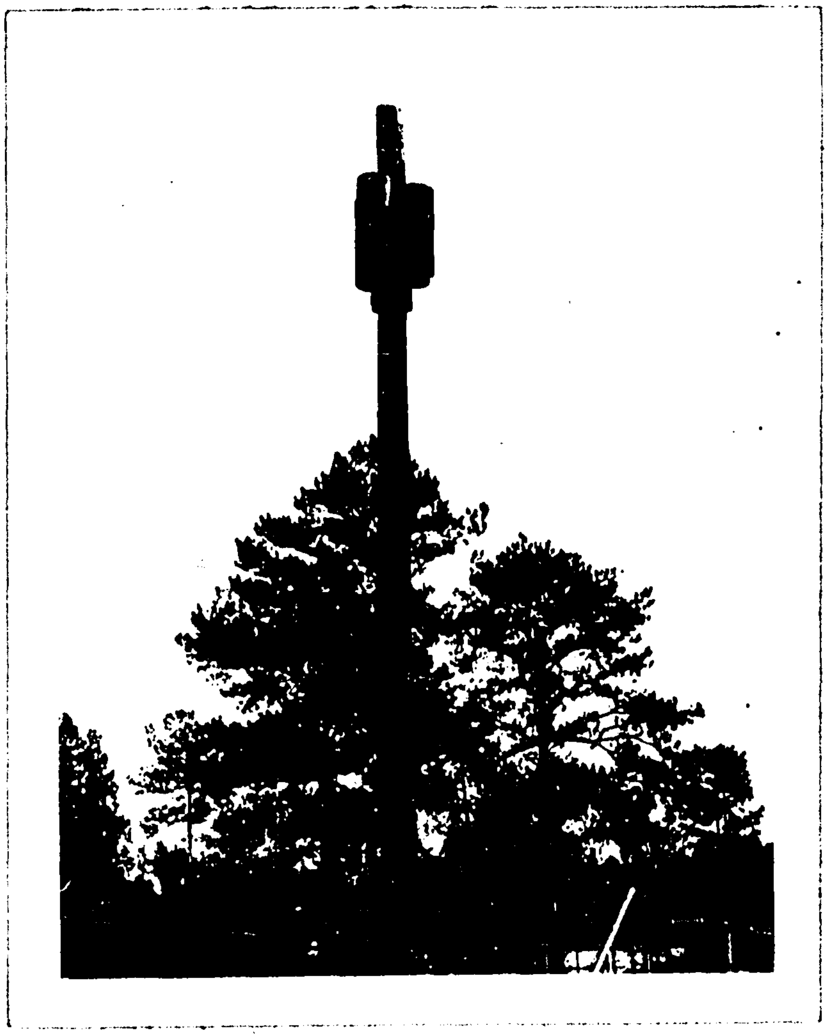


Figure 25. Four simulated woodpecker cavities used to catch rainfall. (Alexandria Forestry Center, Rapides Parish, Louisiana, 1969.)

Table 15. Amount and percent of rainfall in four woodpecker cavities—azimuths of 83° (1), 173° (2), 263° (3), and 353° (4)

Date checked	Rainfall (inches)	Amount in cavities							
		1		2		3		4	
		Ml	%	Ml	%	Ml	%	Ml	%
12/2/68	3.70	T	0	273	44	280	41	45	6
12/13/68	0.91	0	0	11	7	128	76	16	8
12/19/68	.78	0	0	86	60	45	31	T	0
12/23/68	1.92	0	0	60	19	68	19	30	7
12/30/68	.23	0	0	38	10	T	0	T	0
1/6/69	1.24	0	0	30	14	40	17	T	0
2/3/69	1.05	0	0	36	20	34	17	T	0
2/17/69	1.90	0	0	138	43	32	9	10	2
2/24/69	2.35	0	0	94	24	138	32	34	6
2/28/69	1.00	0	0	32	19	46	25	12	5
3/3/69	.22	0	0	30	8	T	0	T	0
3/6/69	.81	T	0	26	19	40	26	6	3
3/17/69	4.21	T	0	38	5	214	27	10	1
3/25/69	.53	T	0	68	77	74	75	T	0

1/ T = Trace

It was evident that rainfall gets into some woodpecker cavities--certainly those facing the direction of the prevailing rainstorms. Wood must have about 15 percent moisture content (based on oven-dry weight) before decay can begin, and 25 to 32 percent for decay of consequence (Boyce 1961, p. 344). Probably ample moisture to cause decay enters the cavities, but the length of time the wood is maintained at a high enough moisture content to support fungal activity is not known.

Conclusions.--Overall, there was little evidence to support the contention that woodpecker holes lead to decay, at least over a relatively short period of time. The fact that only *Amblyosporium* and other similar fungi were found in the cultures taken from the test sections and from the cavity collected in the field reveals that wood-destroying fungi might not be much of a problem in utility poles if the poles are properly treated. However, if utility companies wanted further assurance against decay, an application of pentachlorophenol to cavities would significantly reduce the probability of occurrence.

PERSONAL OBSERVATIONS

This section contains some of the general information I accumulated over several hundred days in the field. The data are not quantitative but I consider them to be meaningful to this study and they may be helpful in the event that this research initiates future work.

Pileated and Red-headed Woodpeckers both seem to prefer some hardwood trees in their habitat; they frequently nest in hardwoods and obtain much of their food from them. Pileateds are almost exclusively forest birds, most common near stream bottoms or in bottomland hardwoods. Red-heads have a more diverse habitat; they tend toward uplands, are frequent in some mixed farm-and-forest situations, and occur in urban areas where hardwood trees are abundant. Neither species is much of a problem where utility lines pass through pure pine stands. However, in most other rural areas where Pileateds and Red-heads occur they will likely do some damage to the poles.

In some parts of the country large acreages of bottomlands have been cleared for agriculture. Where that has been done the woodpecker problem was solved, for there are no pole-damaging woodpeckers where there are no trees. In other parts damage can be expected to fluctuate with changes in woodpecker populations brought about by extensive changes in habitat, for example, logging or flooding. Briefly, the conditions leading to woodpecker damage do not always remain static within an area. There are instances where most of the damage to lines

occurs fairly soon after they are built and may be the result of new territories being created for birds or old ones being disrupted. However, on other lines damage seems to increase with an apparent buildup in bird populations. The tendency to attack (damage) poles does not seem to be a trait learned by woodpeckers in certain localities, for if other factors of the environment are equal, the birds seem to have the same tendencies irregardless of geographic location.

In an earlier section the deleterious effect of birds' nesting in poles was mentioned. It is possible that old poles are of some benefit to birds because predation of nests in poles by mammalian predators may be less than in nearby trees. A logical predator, the raccoon (*Procyon lotor*), would likely rather climb a tree than a pole. Rat snakes (*Elaphe* spp.), which are other potential predators, supposedly are allergic to even minute quantities of creosote. In 50 or more nests of Pileateds and Red-heads that I kept under close scrutiny at various times during the study I never found an instance of nest predation in poles. I do not know if this is atypical or not, since only a very few nests in trees were studied. I doubt that nest predation would be common, however, regardless of the location of the nests. I have found adult woodpeckers on a nest to be quite aggressive and it is not always easy to dislodge one of the birds from its cavity.

I do not believe that poles are used only by birds forced from more desirable nesting sites. Poles are one of the earliest sites taken for nesting in the spring, which would indicate birds were attracted rather than forced to them. The attractiveness for poles seems to be very strong,

because I have observed numerous pairs having unsuccessful nests due to the creosote in the poles make several nesting attempts. I have also observed competition between pairs of Red-heads for poles; and I have observed competition between Red-heads and Pileateds with Pileateds always retaining the poles or supplanting the Red-heads.

In regards to territoriality I made some preliminary investigations of Pileateds in central Louisiana; and although the observations were too few for valid conclusions, I have made certain assumptions. If territories exist (using territory in its simplest form--a defended area), it is difficult to define their boundaries. Pileateds can readily be observed flying distances of one-half mile or more, flights certain to take them through territories of others when densities are high. Perhaps Pileateds do not rely on overt aggression to create space surrounding a breeding pair; instead, calls might be used to fulfill that function. When a high intensity kuk kuk kuk kuk is given, which is done quite frequently, several birds often reply from great distances, which enables the original caller to know their location. In summary, if Pileateds defend a given area, it is done in a manner creating little interaction and attracting little attention.

Contrariwise, Red-heads can easily be seen and heard defending particular areas during the nesting season and also during winter. On the basis of observations I made, nesting territory was variable in size. One particular utility line through good woodpecker habitat contained nesting Red-heads on several consecutive poles. If a pole was considered the central point, those territories were about five acres in size because the poles were approximately 0.1 mile apart.

Yet on other lines where the population of birds may have been less dense, I observed a few pairs using areas over 10 acres. Although a limited number of observations were made, I am certain that Red-heads are territorial during the nesting season. Furthermore, I believe the wintering territories of birds observed in central Louisiana are considerably larger than those observed by Kilham (1958).

The effect of different preservatives in regards to repelling or attracting woodpeckers has been discussed by personnel from several utility companies. Some engineers have told me that pentachlorophenol is quite repelling to the birds. The opposite opinion can also be found; other engineers have told me that creosoted poles are damaged less than poles treated with pentachlorophenol. I did not compare damage to a wide variety of preservative treatments because field observations and discussions with utility company personnel led me to believe such a study would not be meaningful. All preservative treatments that I observed or have information on are damaged by woodpeckers. It should be remembered also that utility companies want poles that will endure 25 to 30 years in the ground, so more than just a "bird-proof" pole must be considered. Some treatments produce harder poles, but none seems to produce poles hard enough to deter attack. Increased densification of wood as performed in small-scale operations may be adaptable to laminated poles, but as of now the practices are prohibitive in cost.

I was fortunate in having the Saline Wildlife Management Area available for tests. It is difficult to find large areas in which a researcher can place approximately 200 poles for tests. A considerable

number of poles of a particular treatment are necessary to ensure adequate exposure, and hence test pressure, to woodpeckers. Of course the poles have to be distributed over a considerable distance so that a pair of birds cannot establish a territory sufficient in size to include more than one or two poles. If several poles were within a pair's territory the birds would have a wide choice of the treatments while at the same time not permitting other birds to test the treatments. The Saline Wildlife Management Area, because of its high woodpecker population, may have in fact offered too harsh a test for the treatments exposed in that area; however, treatments successful there would probably be successful in any locality.

The amount of money companies are willing to spend on the current preventive, hardware cloth, varies. In some easily accessible, relatively unimportant distribution lines, wrapping the poles is economically unjustified. Important transmission lines, many of which can be reached only with difficulty, require greater consideration and the expense of using hardware cloth may be justified. The almost-blind approach of wrapping every pole of a line traversing extensive distances has led to unnecessary expense, because potential problem areas, and hence damage, can be predicted fairly well.

With certain reservations the problem may be one that utility companies can tolerate. Ground-line decay seems to be more of a problem than decay at woodpecker cavities, and the effect of woodpecker damage on strength does not seem to be as adverse as anticipated. Granted that most companies change-out severely damaged poles as soon as possible, yet numerous field personnel that I have queried have been unable to recall a utility pole actually breaking at a woodpecker hole (Figure 26).

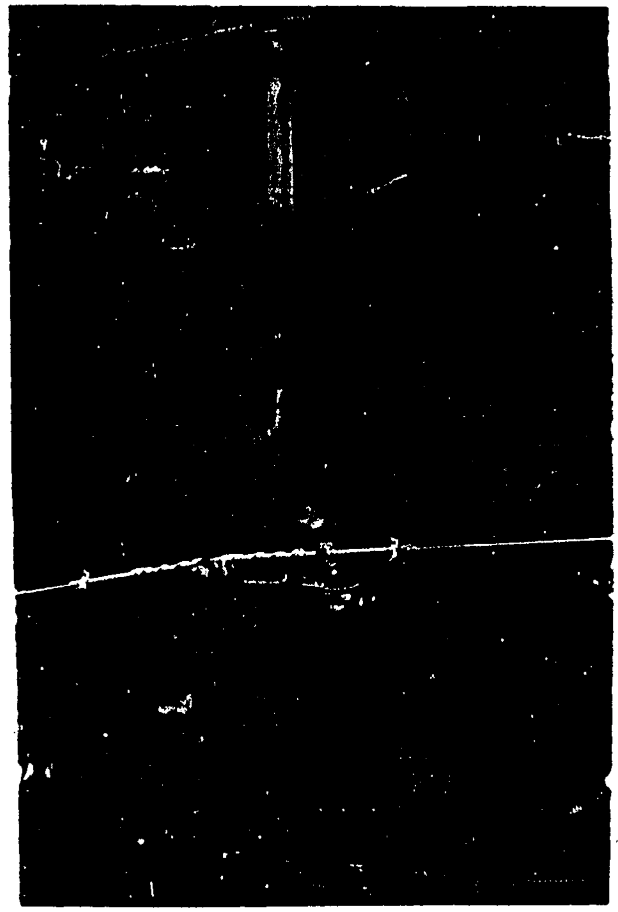


Figure 26. Severe damage does not necessarily lead to pole failure. This pole survived at least 7 years in pictured condition. (Natchitoches Parish, Louisiana, 1965.)

SUMMARY

Various tests were conducted concerning woodpecker damage to poles. Four species of woodpeckers inflict practically all the damage. Utility lines in the southern and eastern states are damaged by Pileated and Red-headed Woodpeckers mostly just prior to the nesting season when cavities are excavated for nests. Many cavities are also used by birds as roosts. Most of the attacks are initiated at those places on poles overlying internal ring shakes. But shake-free poles are not immune to attack.

Repairing the damage, that is filling the cavities, is not a satisfactory practice in itself; if holes are filled the repaired poles should also be wrapped with hardware cloth, but poles with damage should not be wrapped unless the damage is repaired. Birds are able to bend and break the wire over those spots.

Tests with confined birds did not provide any leads for field experiments. Field tests revealed that there is not a natural hardness in poles sufficient to thwart woodpeckers. Coatings and wrappings are effective when birds are unable to maintain themselves on the surfaces. However, durability of the coatings tested was insufficient for acceptance. Only one coating and one wrapping material were found to be completely effective.

Utility companies should reevaluate their thinking regarding woodpecker damage and their expense of preventing it. Strength loss of damaged poles does not seem to be near that anticipated; poles with completed cavities retained much of their original strength. Decay in association with woodpecker damage is not a problem. Rainfall enters the cavities but conditions are evidently not suitable for a long enough time for decay to occur.

It is likely that many companies will continue wrapping every pole of certain lines irregardless of the terrain the utility line traverses. Hardware cloth, because of its high degree of success and its demonstrated durability, will probably continue as the accepted preventive. To supplant it, Vaughn Bar-Bird Shields or any other material will have to offer advantages in cost, durability, effectiveness, or electrical conductivity.

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APPENDIX

Table 16. Random assignment of shake, coating and decoy treatments

Block and pole number	Treatment
Block I	
1212	No shake-coating-no decoy
1111	Shake-coating-decoy
1222	No shake-no coating-no decoy
1121	Shake-no coating-decoy
1122	Shake-no coating-no decoy
1211	No shake-coating-decoy
1112	Shake-coating-no decoy
1221	No shake-no coating-decoy
Block II	
2211	No shake-coating-decoy
2122	Shake-no coating-no decoy
2221	No shake-no coating-decoy
2212	No shake-coating-no decoy
2111	Shake-coating-decoy
2222	No shake-no coating-no decoy
2112	Shake-coating-no decoy
2121	Shake-no coating-decoy
Block III	
3211	No shake-coating-decoy
3121	Shake-no coating-decoy
3221	No shake-no coating-decoy
3222	No shake-no coating-no decoy
3212	No shake-coating-no decoy
3111	Shake-coating-decoy
3122	Shake-no coating-no decoy
3112	Shake-coating-no decoy
Block IV	
4211	No shake-coating-decoy
4112	Shake-coating-no decoy
4122	Shake-no coating-no decoy
4221	No shake-no coating-decoy
4121	Shake-no coating-decoy
4222	No shake-no coating-no decoy
4111	Shake-coating-decoy
4212	No shake-coating-no decoy

Table 16 (Continued)

Block and pole number	Treatment
Block V	
5212	No shake-coating-no decoy
5221	No shake-no coating-decoy
5122	Shake-no coating-no decoy
5112	Shake-coating-no decoy
5222	No shake-no coating-no decoy
5121	Shake-no coating-decoy
5111	Shake-coating-decoy
5211	No shake-coating-decoy
Block VI	
6122	Shake-no coating-no decoy
6211	No shake-coating-decoy
6212	No shake-coating-no decoy
6222	No shake-no coating-no decoy
6112	Shake-coating-no decoy
6221	No shake-no coating-decoy
6111	Shake-coating-decoy
6121	Shake-no coating-decoy
Block VII	
7122	Shake-no coating-no decoy
7212	No shake-coating-no decoy
7211	No shake-coating-decoy
7222	No shake-no coating-no decoy
7221	No shake-no coating-decoy
7112	Shake-coating-no decoy
7111	Shake-coating-decoy
7121	Shake-no coating-decoy

Table 17. Assignment of treatments on Cellon poles in Experiment D

Treatments	Blocks								
	I	II	III	IV	V	VI	VII	VIII	IX
	Pole numbers								
Polyester	1	12	19	35	37	48	62	64	74
Koppers' 200	2	11	23	30	43	53	55	65	73
Baker's EC-167	3	10	20	33	40	52	56	66	76
B. F. Goodrich's 0500	4	13	25	34	42	49	61	63	75
B. F. Goodrich's 7802	5	18	22	36	38	51	60	70	72
Fiberglass	6	15	21	28	44	47	59	67	71
Weyerhaeuser's Wey-fil	7	16	27	29	41	54	57	69	78
Control	8	17	26	31	45	50	58	68	77
Laminate	9	14	24	32	39	46	--	--	--

Table 18. Analysis of variance of woodpecker damage, expressed as damage indexes, on 56 creosoted poles

Source of variation	DF	SS	MS	F
Blocks	6	201.72	33.62	<1
Treatments	7	4,667.41	666.77	5.33**
Shakes (S)	1	70.88	70.88	<1
Coating (C)	1	3,135.02	3,135.02	25.04**
Decoy (D)	1	559.45	559.45	4.47*
S x C	1	161.15	161.15	1.29
S x D	1	141.44	141.44	1.13
C x D	1	355.01	355.01	2.84
S x C x D	1	244.46	244.46	1.95
Error	42	5,257.71	125.18	
Total	55	10,126.84		

* Significant at the 5 percent level.

** Significant at the 1 percent level.

Table 19. Analysis of variance of woodpecker damage to 56 creosoted poles

Source of variation	DF	SS	MS	F
Blocks	6	32.71	5.45	<1
Treatments	7	4,067.12	581.01	18.06**
Shakes (S)	1	168.01	168.01	5.22*
Wrapping (W)	1	3,135.01	3,135.01	97.48**
Decoy (D)	1	196.87	196.87	6.12*
S x W	1	161.12	161.12	5.00*
S x D	1	66.46	66.46	2.06
W x D	1	204.46	204.46	6.35*
S x W x D	1	135.19	135.19	4.20*
Error	42	1,351.01	32.16	
Total	55	5,450.84		

* Significant at the 5 percent level.

** Significant at the 1 percent level.

Table 20. Analysis of variance of woodpecker damage to coated Cellon poles

Source of variation	DF	SS	MS	F
Blocks	8	2,755.8	344.5	1.27
Treatments	7	3,050.4	435.8	5.01*
Error	56	4,871.5	87.0	
Total	71	10,677.7		

* Significant at the 5 percent level.

Duncan's Multiple Range Test[1/]

Treatment:	Wey-fil	Fiber-glass	Poly-ester	EC-167	Control	Koppers 200	BFG-7802	BFG-0500
Mean:	2.67	4.56	5.22	6.00	11.44	13.89	17.89	21.78
	———	———	———	———	———			
						———	———	———
		———	———	———	———	———		
					———	———	———	

[1/]Any two means not underscored by the same line are significantly different at the 5 percent level.

Table 21. Location and treatments involving laminated sections

Pole number	Treatment
Block I (Along Nolan Bayou, LaSalle Parish, Louisiana)	
1 1-1	Chemonite
2 1-2	Dense boards
3 1-3	Phenol formaldehyde
4 1-4	Aluminum embedded
5 1-5	Epoxy and rocks
6 1-6	12-inch square
7 1-7	Control
8 1-8	Acrylic
9 1-9	Vulcanized fiber
10 1-10	South Florida slash pine
Block II (Fence line along Saline Bayou beginning at Duck Slough, LaSalle Parish, Louisiana	
11 2-1	Control
12 2-2	Dense boards
13 2-3	12-inch square
14 2-4	Aluminum embedded
15 2-5	Chemonite
16 2-6	Vulcanized fiber
17 2-7	Epoxy and rocks
18 2-8	South Florida slash pine
19 2-9	Acrylic
20 2-10	Phenol formaldehyde

Table 21 (Continued)

Pole number	Treatment
Block III (Along Muddy Bayou, south of Road 73, south across Ponderosa Road, then south and east toward Jumping Bayou, LaSalle Parish, Louisiana)	
21 3-1	Epoxy and rocks
22 3-2	Chemonite
23 3-3	Acrylic
24 3-4	Aluminum embedded
25 3-5	Dense boards
26 3-6	Phenol formaldehyde
27 3-7	12-inch square
28 3-8	South Florida slash pine
29 3-9	Vulcanized fiber
30 3-10	Control
Block IV (Included in description of Block III)	
31 4-1	Acrylic
32 4-2	Control
33 4-3	South Florida slash pine
34 4-4	Vulcanized fiber
35 4-5	Aluminum embedded
36 4-6	Phenol formaldehyde
37 4-7	Dense boards
38 4-8	Epoxy and rocks
39 4-9	12-inch square
40 4-10	Chemonite

Table 21 (Continued)

Pole number		Treatment
Block V (East and south sides Sec. 16, T.6 N., R.3 E., LaSalle Parish, Louisiana)		
41 5-1		Epoxy and rocks
	42 5-2	Dense boards
43 5-3		Phenol formaldehyde
	44 5-4	Chemonite
45 5-5		12-inch square
	46 5-6	Vulcanized fiber
47 5-7		Acrylic
	48 5-8	Aluminum embedded
49 5-9		South Florida slash pine
	50 5-10	Control
Block VI (Along Hunt Road, south of intersection with Ponderosa Road, then west to Taylor Bayou, LaSalle Parish, Louisiana)		
51 6-1		Acrylic
	52 6-2	South Florida slash pine
53 6-3		12-inch square
	54 6-4	Chemonite
55 6-5		Epoxy and rocks
	56 6-6	Control
57 6-7		Vulcanized fiber
	58 6-8	Phenol formaldehyde
59 6-9		Aluminum embedded
	60 6-10	Dense boards

Table 21 (Continued)

Pole number		Treatment
Block VII (East of Muddy Bayou along Hunt and Ponderosa Roads, LaSalle Parish, Louisiana)		
61 7-1		12-inch square
	62 7-2	Chemonite
63 7-3		Acrylic
	64 7-4	Aluminum embedded
65 7-5		Control
	66 7-6	Vulcanized fiber
67 7-7		Dense boards
	68 7-8	Epoxy and rocks
69 7-9		Phenol formaldehyde
Block VIII (East of Muddy Bayou along Ponderosa Road, LaSalle Parish, Louisiana)		
70 8-1		Phenol formaldehyde
	71 8-2	Control
72 8-3		Acrylic
	73 8-4	Dense boards
74 8-5		Aluminum embedded
	75 8-6	Chemonite
76 8-7		Vulcanized fiber
	77 8-8	Epoxy and rocks
78 8-9		12-inch square

Table 22. Analysis of variance of woodpecker damage on filled and unfilled poles

Source of variation	DF	SS	MS	F
Blocks	7	425.86	60.84	<1
Treatments	1	90.25	90.25	1.002
Error	7	630.29	90.04	
Total	15	1,146.40		

Table 23. Analysis of variance for incidence of fungi in 24 test sections

Source of variation	DF	SS	MS	F
Treatments	3	164.5	54.83	3.51*
50 ml vs. 100 ml H_2O	1	40.33	40.33	2.58
Penta with 50 ml H_2O vs. penta with 100 ml H_2O	1	24.08	24.08	1.54
Penta vs. no penta	1	100.04	100.04	6.40*
Error	20	312.5	15.62	
Total	23	477.0		

* Significant at the 5 percent level.

VITA

Robert Louis Rumsey was born April 10, 1929, at DeRidder, Louisiana. He is the third of six children born to Richard A. and Elizabeth K. Rumsey.

He attended elementary and secondary schools in DeRidder, Beauregard Parish, Louisiana.

In 1952 he entered the U. S. Air Force and served four years as an Airborne Electronics Communications Technician. He was honorably discharged in 1956.

In 1956 he entered Louisiana State University and received a Bachelor of Science degree in Forestry in 1960. He received his Master of Science in Game Management in 1961.

He attended Utah State University from 1961 through 1964 when he left to accept employment with the U. S. Forest Service in Pineville, Louisiana, as a Research Wildlife Biologist.

He reentered Louisiana State University in 1971 and is presently a candidate for the Doctor of Philosophy degree in Forestry.

He has been married to Gloria Maxine Cryer since 1950; they have no children.

EXAMINATION AND THESIS REPORT

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Major Field: Forestry

Title of Thesis: Woodpecker Damage to Wooden Utility Poles

Approved:

Leslie L. Glasgow
Major Professor and Chairman

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Date of Examination:

April 10, 1973