Eastern Wildlife Damage Control Conferences

Seventh Eastern Wildlife Damage Management Conference, 1995

University of Nebraska - Lincoln *Year* 1995

ECOLOGY AND CONTROL OF WILDLIFE DAMAGE TO ELECTRIC SUBSTATIONS

Glenn R. Dudderar* Scott R. Winterstein† Wendy H. Sangstei‡

*Michigan State University, Department of Fisheries and Wildlife
†Michigan State University, Department of Fisheries and Wildlife
‡Michigan State University, Department of Fisheries and Wildlife

ECOLOGY AND CONTROL OF WILDLIFE DAMAGE TO ELECTRIC SUBSTATIONS

GLENN R. DUDDERAR, SCOTT R. WINTERSTEIN, and WENDY H. SANGSTE1
Michigan State University, Department of Fisheries and Wildlife, Natural Resources Building, East Lansing, MI 48824

ABSTRACT: This study addresses several aspects of the ecology and control of wildlife damage to electric substations because the amount *of* existing research *is not* sufficient to make informed decisions about how best *to* minimize that damage. Records of 121 incidents of animal-caused faults showed that 78°I° of the faults were caused by squirrels and raccoons and an average of 2,511 customers lost service doting the outage caused by such a fault. Animal damage control measures were evaluated by observing challenges to cool measures by raccoons and squirrels at a substation. The control measures were breached twice because they had not been properly applied. In *1994, 301* transmission and distribution substations in Michigan were sampled and categorized based on various structural and habitat characteristics. Significant relationships ($p < 0.10$) were *found* between faulted substations and the number *of* nests in the substation, the distance *of* water from the substation, and the beam type used in the substation.

Proc. East. Wildl. Damage Mgznt. Conf. *7;132-138. 1997.*

Animals often use man-made structures for den or nesting sites, foraging sites, or as travel routes, and these activities can cause damage to the structures. Wildlife intrusions into electric power substations and the subsequent damage to those substations is a problem that has received more attention recently by those in the electric utility industry. Wildlife damage to substations comes in the forth of outages, direct equipment damage, and safely and health hazards to maintenance personnel, and it is among the major causes of momentary outages to substations (Warren 1992, Substation Security Working Group 1993). Equipment repair, revenue lost while service is down, and the indirect costs of reduced consumer confidence are some of the expenses associated with power outages. Paula (1990) indicates that some animal-caused outages may cost as much as $500,000.

Electrio utility companies have used a variety of techniques in an attempt to reduce wildlife damage to substations. Among the techniques are chemical repellents, fence barriers, lights, decoys (artificial owls, hawks, snakes, etc.), anti-climbing devices, lineguards, electrical fences, bushing guards, and other structural barriers (Fiske 1990, Substation Security Working Group 1993).

This study addresses several aspects of the ecology and control of wildlife damage to electric substations because the amount of existing research dealing with wildlife damage to substations is not sufficient to make informed decisions about how best to minimize that damage. Therefore, our objectives were to determine characteristics of substations and the surrounding environment that are associated with animal damage and to examine the effectiveness of preventative measures. These objectives were accomplished by completing three different investigations. These investigations were1) the examination of reports of animal-caused faults, 2) the observation of how effectively the current animal damage control measures keep animals out of a substation, 3)the characterization of electric substations based on the relationship between animal-caused faults and structural and habitat characteristics.

This research was requested and funded by Consumers Power because the company was interested in reducing their losses due to wildlife damage.

METHODS

The initial portion of this study involved the examination of data provided by Consumers Power for a period from January, 1988 to September, 1994. Specifically, the analysis involved evaluating numbers and types of animals causing faults, times of faults (month and time of day), the types of substation equipment damaged, the average length of faults, and the average number of customers affected by the fault.

The evaluation of the effectiveness of control measures involved the observation of squirrels and raccoons around a substation in Marshall, MI that is used by the company as a training facility for personnel. In September and October of 1994 study animals were trapped and housed in large outdoor pens at the Dobbie Road Wildlife Research Area at Michigan State University.

In September of 1994, the training facility in Marshall was prepared for observation of the animals and animal proofed by Consumers Power personnel. A 4-ft high polycarbonate fence was put up around two sides of the training facility about 5 ft from the inner substation fence. The outer polycarbonate fence had opaque brown paper affixed to one side so that it was impossible to see through it. The fence immediately around the training facility was animal proofed. Animal proofing measures included the installation of a finch mesh fence and the application of 36-inch wide polycarbonate sheeting around the top of the newly installed fence. Aluminum tie wraps attached the polycarbonate sheeting to the fence and were oriented vertically. The fence and the gate surrounding the substation were to have no openings larger than 1 inch wide. - Gaps at the gate were minimized by applying polycarbonate around the edges of the gate and by sinking the poles of the gate into a concrete base under the gate to maintain proper alignment.

In October 1994 6 raccoons *(Procyon lotor),* 4 melanistic grey squirrels (Sciurus *carolinensus), 1* fox squirrel *(s. niger),* and 1 red squirrel (Tamiascfurus *hudsonicus)* were observed and videotaped to determine whether the control measures used by Consumers Power were **penetrable. Observations of general behavior and** of how an animal gained access to the substation were made. Each animal was observed separately, and observations were made for approximately 2 hours for each animal or until it escaped.

The final part of this study dealt with the classification of substations based on habitat and structural characteristics. The study area for this part of the research encompassed most of the counties in the Lower Peninsula of Michigan. The specific sites studied were distribution and transmission substations located throughout these counties.

A total of 290 distribution and 11 transmission substations owned by Consumers Power were evaluated and classified from May, 1994 to September, 1994. The 88 substations for which Consumers Power had reported wildlifecaused faults in the last six years were included in the 301 substations. The remainder of the 301 substations were randomly selected from among about 1,100 substations that had not been damaged by wildlife in the last six years.

One part of the classification of each of the substations included characterizing the structure of the substation. The structural characteristics recorded were beam construction, physical profile, and degree and type of animal proofmg. Physical profile was recorded as either high or low. A substation with a high physical profile was one with substation components greater than 7m from the ground. A substation with a low profile was one with all substation components less than 7m from the ground. The beam construction for each substation was recorded in terms of beam type, lattice system involved, and the area covered by the structure. Beam types included S-shaped beams (Ibeams), L-shaped beams (angles), and wooden poles. The two beam types most commonly used in substations owned by Consumers Power are Lshaped beams (angles) and S-shaped beams (Ibeams). L-shaped beams are associated with a lattice system, whereas the S-shaped beams are not.

An additional variable that was considered was the number of bird nests in each substation. The number of nests seen, the location of each nest, and when possible the species of bird associated with the nest were recorded.

The substations were also categorized based on the surrounding habitat. For each substation visited, habitat sampling occurred in a rectangular plot that included the area within 100m from each side of the substation. Each plot was then divided into four sections based on the four sides of the substation. Species composition and density of woody vegetation within each segment were recorded. Manmade structures were evaluated in terms of size, number, and type of structures. Manmade structures included fences, cables, houses, and buildings. The distance of the substation from water and the type of water system was also noted. Categories for this variable were water <50m or water 50m-150m from the substation.

Finally, the substations were classified based on the spatial arrangement of the habitat characteristics. Habitat ***for this*** classification was defined as areas having at least 120 trees/ha (3 trees/250m2) with a dbh of at least 20cm or areas having at least 50% crown cover of woody vegetation shorter than Sm tall. This definition was considered to be broad enough to provide an indication of adequate habitat *for* all of the species involved. The spatial arrangement of habitat was defined by the following categories: 0 = no habitat (as defined above) within SOm of the substation on any side; 1= habitat on one side of the substation within SOm; 2, = habitat in two adjacent sides of the substation within SOm; 2b = habitat on two opposing sides of the substation within SOm; 3 = habitat on three sides of the substation within SOm; 4 = habitat on all four sides of the substation within SOm.

Tests' of association were performed to establish Whether there were significant associations between damage and habitat and structural characteristics. Chi-square analysis was performed on all contingency tables *for* which the test was valid. For the tables with sample sizes too small to get valid chi-square tests, Fisher's exact test was used. An association was considered significant for tests with p<0.10.

In order to analyze the capability of habitat and structural variables considered in ' study to predict damage to electric substations, logistic regression model was created from 234 0 the substations classified in the field analysis. Fifty substations were randomly selected from the sampled substations and were used to test the' predictive ability of the model. Substations were classified as faulted if the predicted probability of experiencing a fault was greater than 0.50.

RESULTS

Examination of Records of Animal-caused Faults

Records of animal-caused faults to electric substations between 1988 and 1993 showed that 121 incidents of animal-caused faults occurred in 88 of the 1,177 transmission and distribution substations owned by Consumers Power. Squirrels accounted for 57% of all animal-caused faults. Forty-two percent of all damage caused by squirrels occurred in June, September, and October. Seventy percent of squirrel-caused faults occurred between 0600 and 1200.

Raccoons were found to have caused 21% of the reported animal-caused faults. Damage caused by raccoons in April, May, and August accounted for 65% of damage by raccoons over all months. No raccoon-caused damage occurred in November through February. Raccoon damage was most common between the hours of 2100 and 0600.

The most commonly damaged and replaced items in a substation were fuses (54%), and insulators were the second most damaged item (10%). Outages occurred in all but three of the 121 reported faults. An average of 2,511 customers per outage were affected, and the average amount of time that a fault lasted was one hour and 46 minutes.

Evaluation of Control Measures

In the evaluation of the effectiveness of control measures, one raccoon penetrated the control measures by finding the only missing tie wrap on the burner in about eleven minutes. The Raccoon then pulled the polycarbonate away from *the* fence and climbed under it until he reached the top of the fence.

Of the squirrels observed at the facility, ply 1, a black squirrel, breached the control measures. The squirrel found a 15/s-inch gap between the fence and the gate. It took the squirrel about 65 minutes to find and escape through the hole.

Classification of Substations

The results of tests of association between substations that had been damaged and those not damaged showed that three of the variables measured in the field analysis were significantly associated with faults, at a significance level of p < 0.10 (Table 1). These variables were beam construction (Fisher's exact test, p = 0.019), distance of water from the substation (chi square test, p = 0.051), and number of nests in the substation (chi square test, p = 0.003).

Damage caused by squirrels was significantly associated with beams structure (pa0.001), but beam structure was not significantly associated with damage by raccoons or by birds although sample sizes were much smaller for these two categories.

The association between damage and the distance of water from a substation was significant (p = 0.051) for damaged versus undamaged substations. Faults caused by squirrels and by birds were not significantly, associated with distance from water, but raccoon-caused faults were significantly associated with the distance of water from a substation (p = 0.017). Substations within 50m of water seem to be particularly susceptible to faults caused by raccoons.

The results show that the presence of nests in a substation is significantly associated with damage to the substation (p = 0.003). Squirrel and bird-related faults were significantly associated with the number of nests at a substation but raccoonrelated faults were not.

Although none of the categorizations of habitat were significantly associated with animalcaused faults in general, there were significant associations for squirrel-related faults. When damage by squirrels was analyzed for substations placed into habitat categories based on hypotheses about the spatial arrangement of habitat, a significant relationship was found (p = 0.094).

The logistic regression model created from field variables correctly predicted whether or not a substation had experienced an animal-caused fault for 56% of the 50 samples.

DISCUSSION

Examination of Records of Animal-caused Faults

The data provided by Consumers Power from reports of animal-caused faults to electric substations between 1988 and 1993 helped to define *the general* nature of the problem of animal damage. According to the records, squirrels accounted for 57% of all animal-caused faults. These results correspond very well to those of Enck (1989) who found that 55% of all animal-caused faults were caused by squirrels. Raccoons were found to have caused 21% of the reported animal-caused faults, which was a higher percentage than the 12% found by Erick (1989). The tames of day and year that damage occurred seemed to reflect the daily and seasonal behavioral patterns of raccoons and squirrels (Schneider 1973, Cauley 1974, Hoffiman and Gottschang 1977, Thompson 1978, Thompson and Thompson 1980, Feel 1982).

The Consumers Power records additionally provided information about direct and indirect costs incurred because of animal-caused faults. Costs to utility companies included the loss caused by damage to substation equipment, the revenue lost while power was out, and the indirect cost of reduced consumer confidence. The results of this study show that these costs are potentially very high. In a study by Erick and Brown (1989) combined direct and indirect costs of animal-caused faults for six utility companies in New York state were estimated to be as high as $10 million over an eight year period.

Evaluation of Control Measures

Observations of raccoons and squirrels at the animal-proofed training facility indicate that control measures are effective if correctly and completely applied, but proper application is critical. The only raccoon to thwart the control measures was able to find the only missing tie on the polycarbonate barrier in about eleven minutes. The fact that it took only eleven minutes for the raccoon to find the missing tie suggests that even one minor flaw is enough to make the substation fence penetrable. As with the raccoon, a squirrel found a flaw in the animal proofing. This time it was a 11/8inch gap between the fence and the gate. Here again is evidence that the correct application of damage control measures is important if they are the be entirely effective.

Although the control measures did not keep two of the animals out of the substation, they did prevent ten others from entering. Therefore, it appears that the control measures are effective but that this effectiveness is compromised by flaws in application. Of 43 substations treated with animal proofing observed in the field, only I was completely and correctly treated, indicating that effectiveness is not 100% at any of the other substations.

Classification of Substations

One way to aid in the prevention of animalcaused faults at substations is to understand what makes the substation susceptible to faults. This approach narrows the scope of the problem by identifying characteristics to be targeted with preventative measures and by identifying substations most likely to be damaged based on the set of characteristics.

In the comparison of substations that had been damaged and those not damaged, three of the variables measured in the field analysis significantly associated with faults ($p < 0.1$ These variables were beam construction ($p = 0.01$ distance of water from the substation ($p = 0.05$ and number of nests in the substation ($p = 0.003$

The substation structures most responsible for susceptibility to damage are those involving shaped beams, particularly those that cover an

greater than 100m2. The reason for this structure being more susceptible could be because these structures are easily climbed by raccoons and squirrels and because they provide good nesting locations for birds.

The presence of nests in a substation was also significantly associated with damage to the substation ($p = 0.003$). The presence of at least foot nests in a substation seems to be particularly indicative of damage. Nests might attract foraging animals to a substation, but it is also likely that damage and the number of nests are associated because of some habitat or structural component to which they are both correlated. Independence of the variables in the study was difficult to analyze because sample sizes for certain combinations were extremely low. However, there were no obvious associations between nests and the other variables. Therefore, if nests are correlated with same habitat or structural component, it could be one that was not recorded in this study.

The final variable considered in the field analysis was vegetative habitat. A study by Erick and Brown (1989) found no correlation between surrounding habitat and the number of faults at a substation. However, the relationship between habitat and wildlife damage may not have been fully described by the study. One possible reason for their findings is that the correct habitat variables were not used Another possible reason is that there is a non-linear relationship between the amount of habitat surrounding the substation and the amount of damage to the substation. For example, in areas with few trees there may be little damage to substations because there are no squirrels in the area. There may also be little damage in areas with many trees because the animals would not need to use the substation as a travel route and would have **plenty** of available habitat. In areas with moderate mounts of trees, the most damage would be seen because: animals would use substations for activities such as travelling or searching for food or shelter. Based on this fit, we hypothesized that damage would occur most often in substations with vegetative habitat on two or three sides of the won, less often in substations with vegetative habitat on one or four sides, and least often in substations without any vegetative habitat surrounding it.

The data from the field generally reflected this hypothesis, although the relationship between the three generalized categories and animal-caused faults was not significant. However, when damage by squirrels was analyzed for substations placed in the three habitat categories, a significant relationship was found (p = 0.094). The fact that a significant relationship was found for squirrels but not for the other animals probably reflects that the hypothesis that established the habitat classifications was based largely on the predicted behavior of squirrels. The smaller sample sizes for raccoons and birds could also have influenced the analysis.

The above results suggest that there is a relationship between vegetative habitat and animalcaused faults to substations. In particular, squirrels are most likely to cause faults in substations that are surrounded by vegetative habitat on two or three sides and least likely to cause faults in substations with no vegetative habitat within SOm.

The logistic regression created with the field variables was not a highly predictive one. In theory, this type of model could be used to predict whether or not a substation will be damaged in the future, but the model would have to be substantially improved by considering additional explanatory variables. However, it is likely that a highly predictive model would be extremely difficult to create. Regardless of *whether the* model is used to predict faults, it illustrates how the different habitat and structural components associated with a substation can be used in combination to assess the likelihood of a substation experiencing an animalcaused fault.

MANAGEMENT IMPLICATIONS

Several recommendations about how to prevent animal-caused faults can be made based on the results of this study.

1) Certain characteristics of the habitat and of the structure of a substation should be considered when a new substation is built.

-- avoid building substations in areas within SOm of lacustrine or riverine habitat.
-- attempt to build substations in areas with very few trees or shrubs or in areas with vegetation on either one side or on all four sides.

-- build substations with beams that are least conducive to climbing and nesting activities (not L-shaped beams).

2} Preventative measures should be used on existing substations that have structural and habitat characteristics that make them susceptible to animal damage. The more of the following characteristics a substation has, the higher priority it should have for animal proofing:

-- substations with at least four bird nests in them

-- substations constructed out of L-shaped beams
-- substations located within SOm of water

-- substations with vegetative habitat on two or three sides

3) Inspect treated substations to insure that control measures have been thoroughly and precisely applied.

The decision about which substations to treat with control measures should involve the evaluation of the structural and habitat characteristics of a substation in addition to the evaluation of records of previous damage to a substation. This approach should *help to* more successfully prevent wildlife damage to substations.

LITERATURE CITED

Cauley, D.L. 1974. Habitat requirements of four selected species in the urban environment. Ph.D. Thesis, Michigan State University. 66pp.

Enck, J. W 1989. Wildlife damage in electric substation in New York. Pages 225-232 *in* S. R Craven, ed. Proc. Fourth East. Wildl. Damage Control Conf. Madison, Wl.

and T. L. Brown. 1989. Animal deterrents for electric substations. Final report: ESEERCO project EP 87-11. 76pp.

Fiske, J. 1992. Electric fence promises to keep squirrels away. Electrical World. 206(11):46-47.

Fogl, J. G. 1982. Ecology of melanisitic gray squirrels *(Sciurus carolinensis)* and fox squirrel (S. niger)in an urban area. Ph. D. Thesis, Michigan State University. 143pp.

Hoffman, C. O. and J. L. Gottschang. 1977. Numbers, distribution, and movements of raccoon population in a suburban residential community. J. of Mamm. 58(4):623-636.

Paula, G. 1990. Prevent animals from damaging substations. Electrical World. 204(3):S47S49.

Schneider, C. 1973. The adaptable raccoon. Nat. Hist. 82(8): 64-71.

Substation Security Working Group. 1993. IEEE guide for animal deterrents for electric power supply substations. Institute of Electrical and Electronics Engineers, Inc. New York. 16pp.

Thompson, D. C. 1977. Diurnal and activity of the grey squirrel. Can. J. 55:1185-1189.

-,and P J. Thompson. 1980. Food habits caching behavior of urban grey s Can. J. Zool. 58:701-710.

Warren, C. M. 1992. The effect of r momentary outages on distribution reliability indices. IEEE Trans. on Power Delivery. 7(3). 1610-1615.