REPELLENTS

A number of studies have attempted to evaluate the impact of chemical and biological repellents on animal feeding. Some of these studies are summarized in this document (*1*, *2*, *3*, *4*, *5*, *6*, *7*, *8*). It has been speculated that the application of repellents on roadside vegetation might be used to deter deer browsing and possibly reduce the number of deer-vehicle crashes (DVCs). Unfortunately, no research was found that discussed or tested the DVC impact of repellents applied in the field along a roadway, or attempted to evaluate the other impacts or factors that might need to be considered in an application of this type.

Repellents reduce animal feeding by making a source of food taste unpleasant (this is referred to as a contact repellent) and through offensive (typically predator-related) smells (this is referred to as an area repellent). A number of chemical and biological repellents are available that use these approaches. The studies summarized in the following paragraphs evaluate the impact of one or more repellents on the eating habits of captive white-tailed deer, mule deer, caribou, and/or elk. These animals all have similar predators and were expected to have somewhat similar responses to particular repellents. The "Conclusions" section of this summary discusses some of the potentially confounding factors that should be considered in the use and comparison of the studies reviewed, and also describes the results of an analysis and ranking of repellent effectiveness completed by Hani and Conover (*8*). Their analysis and ranking activities included five of the references reviewed in this summary plus seven others (*9*, *10*, *11*, *12*, *13*, *14*, *15*). The results from a recently completed review to determine the potential of an area repellent system to keep ungulates away from roadways are also described (*16*).

Literature Summary

White-Tailed Deer

During the winter season of 1989 and 1990 Swihart, et al. conducted a study that tested the effectiveness of three predator odor repellents on white-tailed deer consumption of shrubs (*1*). The trials evaluated the effectiveness of urine from bobcats, coyotes, and humans (*1*). In general, some of the factors that might impact a response by a white-tailed deer to predator odors could include whether the predator and prey consistently co-exist in the same space, the length of the association between the predator and prey, and to what extent a flee response to a predator can or has been passed on by members of the prey species (*1*). Based on this knowledge, Swihart, et al. hypothesized that the white-tailed deer repellency of the predator urine odors they considered would decrease in the following order: bobcat, coyote, and human (*1*).

During the first trial, a tube containing predator (i.e., bobcat, coyote, and human) urine was attached to transplanted Japanese yew shrubs in a wooded test area (*1*). Distilled water tubes (as a control) and those with the urine treatments were attached to the yew shrubs in a random manner (*1*). The percentage of shoots browsed was then measured. Overall, an increase in browsing was observed with time, but the yew shrubs treated with bobcat and coyote urine were browsed at a significantly lower level than those treated with water or human urine (*1*). In addition, the shrubs treated with bobcat urine were browsed significantly less than those treated with coyote urine (*1*).

During the second trail, Swihart, et al. tested whether a weekly topical spray application of bobcat and coyote urine would be more effective than the hanging of tubes at repelling white-tailed deer (*1*). One yew shrub in each test plot was sprayed with a urine mist, and it was found that this shrub received less white-tailed deer browsing than the control trees (which had experienced browsing similar to that which occurred in trial one) (*1*). Swihart, et al. concluded that the repellency (as measured by percent shoots browsed) of the bobcat and coyote urine was still significantly greater than human urine, and that the repeated topical applications (versus tube hanging) significantly increased repellency (*1*).

A related third trial included yew shrubs and also added several Eastern Hemlock tree branches to the experimental plots. Some of the plots were sprayed with bobcat and coyote urine once or twice weekly (*1*). Other plots served as a control and were sprayed with distilled water. The researchers found that the spraying of bobcat and coyote urine on the Eastern Hemlock decreased the white-tailed deer browsing more than that experienced with the yew experiments (*1*). However, the authors were unable to conclude that the increased frequency of application produced any additional reductions (*1*).

Overall, Swihart, et al. made several conclusions based on their experimental results (*1*). First, human urine appeared to be ineffective as a white-tailed deer repellent (*1*). They speculated that this result might be due to the relatively short period of co-existence between humans and white-tailed deer. In other words, the smell of humans did not result in the same naturalistic flee mechanism that would occur with the apparent presence of a bobcat and coyote. Second, Swihart, et al. concluded that their evidence appeared to show that white-tailed deer could distinguish between predator and non-predator odors, and that the coyote and bobcat urine in tubes became less effective with time (*1*). These results could have been caused by white-tailed deer habituation or the evaporation of the repellent components, but Swihart, et al. believed it was evaporation because their reapplication of the repellents resulted in a larger reduction in browsing (*1*).

Mule Deer

Sullivan, et al. have completed research on the repellency of predator odors on the feeding patterns of mule deer (*2*). They specifically tested the effectiveness of cougar, coyote, bobcat-lynx (mixture), jaguar, and wolf feces odors, and the urine odors of coyote, wolf, lynx, bobcat, fox, and wolverine (*2*). During seven test trials, these materials, as well as human urine, ammonia, and/or other commercial repellents were applied to Salal (a type of shrub) leaves and/or two types of coniferous seedlings using several methods. In some cases the feces were mixed with water and placed on the plant, and the ammonia and human urine were placed in vials located near the leaves. In other cases, fecal extracts were mixed with an adhesive and painted on nearby stakes (*2*).

When the different extracts were applied to the plant or used as an adhesive it was concluded that the predator feces (e.g., cougar, coyote, and wolf) odors significantly suppressed (sometimes completely) the browsing by mule deer (*2*). The vials of human urine resulted in no significant difference (when compared to the control) in the mule deer browsing (*2*). The vials of ammonia reduced browsing for the three days considered, but to a significantly smaller level than the wolf or jaguar feces (*2*). Coyote, wolf, and jaguar fecal odors, whether in vials or used as an adhesive, also significantly reduced Salal browsing. Finally, all the predator urine odors were found to significantly reduce Salal browsing (*2*). The coyote odor had the most consistent Salal browsing reduction results, but also reduced the coniferous browsing (*2*).

Overall, the Sullivan, et al. study indicated that predator orders could be an effective mule deer repellent using any of the three application methods considered (*2*). In 1978 Melchiors, et al. also found that predator fecal odors reduced the feeding of mule deer (*3*). Unlike the later Sullivan, et al. study, however, Melchiors, et al. found that feline odors were more effective than canine odors (*3*).

Andelt, et al. also evaluated the effectiveness of several repellents on mule deer (*6*). The details of the experimental design used in this study are similar to that of another Andelt, et al. study described in the "Elk" section of this summary (*5*). Overall, this study found that McLaughlin Gormley King Company™ Big Game Repellent (BGR), whole chicken eggs, and coyote urine were more effective at repelling mule deer than Hinder™, bars of soap, Ro-pel™, and thiram. However, none of the repellents tested did deter mule deer when they were hungry (*6*). This study also showed a decrease in the effectiveness of *odor* repellents (i.e., BGR, coyote urine, and chicken eggs) with time, and an increase in effectiveness with time of the thiram taste repellent (*6).* However, Andelt, et al. also concluded that water sprinkled on apple twigs after the application of the repellents somewhat decreased their effectiveness (*6*).

Caribou

In 1998, Brown, et al. studied 14 captive caribou to test the feeding deterrent capabilities of Wolfin™, Deer Away™ BGR, and lithium chloride (LiCl) (*4*). They speculated that these repellents might be combined with roadway sand-salt mixtures and/or applied adjacent to roadways to reduce DVCs (*4*). The Wolfin™ was tested by observing the feeding patterns of caribou when a capsule of the material was placed near their food tubs. Capsules of Wolfin™ with the substance (at concentrations five times the manufacturer's recommendation for roadside use) were placed approximately 6.6 feet from the food tubs (*4*). The BGR and LiCl repellents were tested by combining them with the caribou food.

The reaction of the caribou to each repellent was measured by recording the quantity of food consumed, the time spent feeding, and the number of feeding bouts (i.e., the number of separate instances a caribou lowered its head to the food, turned away, and then moved more than 3.3 feet) (*4*). Observations were made for two days prior to the treatment, during the five days of each treatment, and for two days after the treatment.

Each repellent had a different impact on the feeding patterns of the caribou. Overall, the researchers concluded that the captive caribou did not appear to be affected by the Wolfin™ (*4*). They continued to feed with the Wolfin™ nearby, showed a slight increase in feeding time, and an increase in the number of feeding bouts (*4*). Conversely, on the first day of the BGR treatment the caribou did not consume any of the treated food, and the length of caribou feeding time initially decreased (*4*). During the remainder of study period, however, feeding time and quantity slowly increased and returned to those similar to pre-treatment levels (*4*). This feeding pattern could be the result of habituation or increased hunger by the caribou. Feeding bouts only slightly decreased during the treatment period (*4*). The application of the LiCl resulted in an immediate 25 percent reduction in the quantity of treated food consumed, and the feed was entirely rejected throughout the remainder of the study period (i.e., the caribou ate the LiCl, were sick, and did not return) (*4*). The number of feeding bouts and total feeding time did increase at the start of LiCl treatment, but then continued to decline during the study time period (*4*). The number of feeding bouts appeared to initially increase because the caribou would check the food more often and then leave it alone if it was still treated (*4*). In the post-treatment period, the quantity of food consumed increased immediately. Brown, et al. also noted that the caribou appeared to seek water more often when the LiCl was applied (*4*).

Brown, et al. also suggested that the caribou did not appear to be repelled by the Wolfin™ because their motivation to feed may have been greater than the odor avoidance impact, and/or the animals may not have recognized the odor of a predator (*4*). The pattern of feeding observed with the BGR application also appeared to indicate some habituation to the repellent, and the LiCl was the most effective caribou repellent tested (*4*). Unfortunately, according to the authors of this study, the use of LiCl as a repellent may also initially increase the feeding time of animals (*4*). This side effect may remove this repellent as an option for applications along roadways (*4*). In addition, it may also have some negative effects on other animals (*4*). Past research and field studies have also produced inconsistent results, and although LiCl is not considered hazardous, there have been examples where non-targeted animals have died from ingesting too much of it (*4*). These observations suggest that more research is needed.

Elk

Research similar to that described above was also completed by Andelt, et al. (*5).* They evaluated the repellency of McLaughlin Gormley King Company™ BGR, chicken eggs, coyote urine, Hinder™, Hot Sauce Animal Repellent™, Ro-pel™, and thiram on captive female elk (*5*). In one trial, each of the repellents was sprayed on alfalfa cubes and fed to the elk. Observations were then made of the quantity of food consumed. In a second trial, the food supply was reduced for several days to increase the hunger of the test animals and the treated food was then supplied (*5*). Finally, in a third trial, Andelt, et al. tried to determine the minimum repellent concentration levels that would inhibit elk browsing of apple tree twigs (*5*).

Overall, the effectiveness of the repellents studied by Andelt, et al. was related to the hunger level of the elk, the palatability of what was consumed, and the concentration of the repellent (*5*). For example, the hungry elk ate more treated apple twigs than those that were regularly fed (*5*). In fact, hunger appeared to reduce the effectiveness of all the repellents tested except for a 6.2 percent concentration (at 100 times the recommended for deer) of Hot Sauce Animal Repellent™ (*5*). This concentration of animal repellent deterred all the well-fed elk and the majority of the hungry elk (*5*). The application of the recommended concentration of Hot Sauce Animal Repellent™ for deer, however, failed to deter hungry elk and most of the regularly fed elk (*5*). The coyote urine concentrations that Andelt, et al. tested also failed to deter the hungry elk, and only reduced the feeding levels of some regularly fed elk when it was applied at full strength (*5*). Similar results were found when the recommended concentration of thiram was tested (*5*).

In general, Andelt, et al. concluded that BGR and coyote urine were more effective than the chicken eggs and other repellents at decreasing the feeding activities of elk on alfalfa cubes (*5*). The effectiveness of the repellents based on *odor* (e.g., chicken eggs) also appeared to decrease during the study period and may have been caused by elk habituation (*5*). The *taste* repellent tested (i.e., thiram), however, reduced feeding during the entire study period (i.e., after the initial taste) (*5*).

Conclusions

A number of studies have attempted to evaluate the effectiveness of numerous repellents on the feeding patterns of several different types of captive animals (*1*, *2*, *3*, *4*, *5*, *6*, *7*). The studies summarized here investigated different repellent impacts on white-tailed deer, mule deer, caribou, and elk. Unfortunately, the descriptions in this document reveal, for the most part, that these studies were designed in an inconsistent manner and focused on several specific factors that may impact repellent effectiveness. Some of the different factors evaluated include type and number of repellents (e.g., predator urine, brand, odor, taste, etc.), status or application of repellent (e.g., spray, paste, etc.), concentration of repellent, animal hunger level, food type, and amount of rain or water occurrence after repellent application. All of the studies did find some type of feeding reduction with one or more of the repellents considered, but the variability and/or non-repeatability of the studies makes a direct comparison of their results difficult. Any comparison would require an assumption of equality in the validity and robustness of the results from these multiple studies. An attempt to discover some trends in these and other repellent studies is described below.

Hani and Conover did reach conclusions similar to those stated above when they evaluated five of the studies described in this document and seven others (*1*, *2*, *3*, *5*, *6*, *8*, *9*, *10*, *11*, *12*, *13*, *14*, *15*). They also decided to rank, analyze, and then evaluate the repellent effectiveness results of all twelve studies, and attempt to define some overall trends (*8*). All of these studies evaluated by Hani and Conover focused on the effectiveness of two or more repellents (*8*). First, they summarized the species considered (i.e., white-tailed deer, mule deer, and elk) in each study, the food used, and whether the study was a field test (*8*). Then, they ranked (i.e., 0 = ineffective to 4 = highly effective) the effectiveness results for each repellent considered in the studies they reviewed (*8*). These rankings were then statistically analyzed.

Overall, Hani and Conover concluded that BGR and predator odors were typically shown to be the most effective of all the repellents considered in the studies they evaluated (*8*). In addition, they found no significant difference in the ranking of area (i.e., primarily odor) and contact (i.e., spray or dust) repellents, or in the reactions to repellents between deer and elk (although white-tailed and mule deer appeared to react differently to predator odor) (*8*). Factors found to impact the effectiveness of repellents included the relative palatability of the plant protected, local deer herd populations, availability of other food, weather, amount and concentration of repellents, and study/test duration (*8*). The results of the Hani and Conover evaluation may be useful when choosing a repellent, but should also be used with the understanding that the comparison required a subjective, but expert, ranking to be completed. An assumption that all the studies they evaluated were equally valid and comparable results was also required.

In 2003, Kinley, et al. also completed a detailed literature review and qualitative summary of a large number of studies to investigate the potential for an area repellent system to keep ungulates away from roadways (*16*). Their document contains more than 75 references in its bibliography, and has a table that summarizes the results of more than 265 repellent tests (*16*). After a review of this information they determined that the area-based repellents with the most potential to keep ungulates away from roadways were putrescent egg and natural predator odors (*16*). However, their potential still needs to be tested in the field. It was also noted that there should not be an expectation that one repellent will result in complete deterrence, or that the choice of which specific repellent (e.g., type of predator odor or repellent brand name) to use for roadside purposes is obvious (*16*).

Despite the number of repellent effectiveness studies on captive white-tailed or mule deer, no studies were found that documented an attempt to test repellent effectiveness on deterring wild animals from crossing a roadway. It should also be recognized that the reaction of captive and non-captive animals to some repellents (e.g., predator urine) might vary because captive animals may not associate these odors with danger. The significance of this difference, however, still needs to be measured because it appears that some of the reaction to predator odor could be genetic rather than learned (*7*).

The effective application of repellents (chemical, biological, acoustical, etc.) to reduce roadside browsing of white-tailed deer is based on several factors. These factors include, but are not limited to, how the repellent is applied, at what time intervals, cost, animal habituation, and the locations to which is it applied. Like most of the other countermeasures already summarized, the application of repellents as a DVC reduction tool would also most likely need to be focused on "high" DVC locations rather than widespread. In addition, white-tailed deer (or other animals) may just shift their browsing location if repellents are not applied in a widespread manner (but this would also have its own undesirable ecological impacts). Studies have shown that animals may habituate to repellents, and if they are hungry may even browse plants treated with repellents. In fact, Kinley, et al. suggest that repellents would be most effective if used at specific locations for the short-term (*16*). In addition, the application of repellents in combination with other DVC reduction tools at "high" crash locations might be considered for maximum effect. Finally, other factors that need to be considered in the application of repellents are their impact on non-targeted animals and their possible impacts on the general environment. Clearly, additional and repeatable research needs to be completed in this field to determine the actual impact of repellent application on the number of DVCs.

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