

# Role of Predator Odor in Roost Site Selection of Southern Flying Squirrels

JENNIFER S. BORGIO,<sup>1</sup> Jack H. Berryman Institute, Utah State University, Logan, UT 84322-5230, USA

L. MIKE CONNER, Joseph W. Jones Ecological Research Center, Newton, GA 39870, USA

MICHAEL R. CONOVER, Jack H. Berryman Institute, Utah State University, Logan, UT 84322-5230, USA

## Abstract

Roost site selection should be influenced, in part, by predator avoidance strategies. Prey species may use olfactory cues to assess predation risk. Our objective was to determine if southern flying squirrels (*Glaucomys volans*) use olfaction for assessing predation risk and selecting safe roosting sites. We tested the response of captive flying squirrels to several scents placed inside nest boxes. Squirrels spent significantly less time overnight in nest boxes scented with fox squirrel (*Sciurus niger*) fur, bobcat (*Lynx rufus*) fur, red fox (*Vulpes vulpes*) urine, raccoon (*Procyon lotor*) fur, king snake (*Lampropeltis getula*), and corn snake (*Elaphe guttata*) than unscented (control) boxes. Nest boxes with gray squirrel (*S. carolinensis*) fur, red fox urine, raccoon fur, and corn snake scent were selected as daytime roosting sites less than would be expected by chance. Southern flying squirrels are a major usurper of red-cockaded woodpecker (*Picoides borealis*) cavities and may reduce reproduction in this endangered bird. Our results indicate that predator odor may be an effective means of deterring flying squirrels from roost sites. If so, predator scent application could be utilized to reduce negative impacts of flying squirrels on red-cockaded woodpeckers. (WILDLIFE SOCIETY BULLETIN 34(1):144–149; 2006)

## Key words

behavior, deterrent, flying squirrel, Georgia, *Glaucomys volans*, olfaction, *Picoides borealis*, predation risk, predator, red-cockaded woodpecker, roost.

Habitat selection, including that of a roosting site, should be governed, in part, by the need to avoid predation (Lima and Dill 1990, Sweitzer and Berger 1992, Kats and Dill 1998). This is especially true when selecting roosting sites because, while roosting, animals are less vigilant and more vulnerable to predation than at other times (Sweitzer and Berger 1992, Hendricks 2000). One way animals can reduce the risk of predation is to avoid those roost sites which have a high risk of predation. Visual, olfactory, or auditory cues may be used to assess the potential for risk (Merkens et al. 1991, Herman and Valone 2000). For instance, some animals, such as water skinks (*Eulamprus heatwolei*), pocket gophers (*Thomomys talpoides*), and voles (*Microtus* spp.), avoid shelters where they detect predator odors (Stoddart 1976; Gorman 1984; Sullivan et al. 1988a,b; Sullivan et al. 1990; Head et al. 2002).

Southern flying squirrels (*Glaucomys volans*) are active at night and roost during the day in tree cavities, leaf nests, and nest boxes (Moore 1947, Raymond and Layne 1988). They may use olfaction to assess the predation risk of cavities before selecting a roosting site for a particular day. For a flying squirrel selecting a roosting site, there are 3 possible predation risks. First, the predator may already be in the roosting cavity, lying in wait to ambush the squirrel when it enters the cavity. Second, the predator may enter the cavity while the animal is roosting and kill it. Finally, the flying squirrel may be displaced from its roost during the day, which would increase its predation risk through exposure.

While many species (including black-tailed deer [*Odocoileus hemionus*], mountain beaver [*Aplodontia rufa*], gray squirrels (*Sciurus carolinensis*), and voles [*Microtus* spp.]) have been evaluated for their ability to use olfaction to recognize predators, flying squirrels have not (Gorman 1984, Melchior and Leslie 1985, Sullivan et al. 1985,

Epple et al. 1993, Rosell 2001). Our objectives were to evaluate if flying squirrels are capable of olfactory recognition of predators, and, if so, determine how predation risk affects roost site selection. It is possible that olfactory recognition and avoidance of predators by flying squirrels could be used to reduce flying squirrel use of red-cockaded woodpecker (*Picoides borealis*) cavities. Flying squirrels usurp their cavities, causing decreased reproductive success in the endangered bird (Loeb and Hooper 1997).

We hypothesized that flying squirrels would avoid using roost sites that contain predator odors. We also hypothesized that they should prefer using roost sites that have odors of conspecifics and other squirrels. Their presence should indicate that the cavity had been used as a roosting site in the past and, therefore, may likely be a safe roosting site in the immediate future.

## Study Area

This research was conducted in a climate controlled room on the 11,736-ha Joseph W. Jones Ecological Research Center (Ichauway) in southwestern Georgia. We also collected squirrels from this property. Ichauway was located in Baker County, about 61 km southwest of Albany, Georgia. Predominant habitats on Ichauway included longleaf pine (*Pinus palustris*) savannah and hardwood forest. Wildlife species found in Ichauway were typical of the southeastern longleaf pine community, including raccoon (*Procyon lotor*), bobcats (*Lynx rufus*), red foxes (*Vulpes vulpes*), king snakes (*Lampropeltis getula*), corn snakes (*Elaphe guttata*), fox squirrels (*Sciurus niger*), gray squirrels, southern flying squirrels, and red-cockaded woodpeckers.

## Methods

We removed 82 squirrels from red-cockaded woodpecker cavities, kestrel (*Falco sparverius*) boxes, and bluebird (*Sialia sialis*) boxes at Ichauway. While this capture technique is biased toward flying

<sup>1</sup> E-mail: borgio@cc.usu.edu

squirrels using artificial cavities and nest boxes, it sampled our target population of squirrels (i.e. those using cavities and nest boxes). We housed the captive colony of squirrels in a  $1.2 \times 1.0 \times 1.4$  m pen. We attached 6 nest boxes to the pen and we housed a maximum of 12 squirrels at 1 time. We provided cedar (*Thuja* sp.) shavings on the plexiglass floor of the cage. We fed squirrels a diet of nuts, fresh fruit, and rodent mix and provided water in a bowl ad libidum. We provided an exercise wheel and several branches for activity. We never observed any indication of conspecific aggression due to crowded conditions. Squirrels used 2–3 nest boxes within the cage, with the other boxes remaining unoccupied. We maintained squirrels for  $\leq 2$  weeks, after which we humanely euthanized them (Institutional Animal Care and Use Committee approval #1069, Utah State University).

We randomly assigned 90 squirrels 1 of 3 tests. Test 1 was composed of different squirrel scents: flying squirrel urine and fur, fox squirrel fur, and gray squirrel fur. Test 2 was composed of different scents from mammalian predators: red fox, raccoon, and bobcat. Test 3 was composed of scents from the corn snake and king snake. Within the tests, we assigned squirrels a random scent sequence using a Latin square design (Jones and Kenward 1989).

We purchased bobcat and red fox urine (from animals on a meat diet) from Minnesota Trapline Products (Pennock, Minn.). We physically collected all other samples from dead specimens obtained through Ichauway management practices (mesopredator trapping for northern bobwhite [*Colinus virginianus*] management). We withdrew urine directly from the bladder with a syringe and subsequently refrigerated it. We cut the hide (fur and underlying skin) from the hindquarters of the animals. We kept it frozen when not in use. The bobcat, raccoon, fox squirrel, and gray squirrel fur samples were approximately  $8 \times 8$  cm. The flying squirrel fur samples were approximately  $4 \times 4$  cm. We taped microcentrifuge tubes filled with 0.5 ml of urine samples into previously assigned boxes. We placed the sample in the given tube using a 3-ml microsyringe with a 20-gauge needle. We placed a cotton plug in each tube. We taped a microcentrifuge tube filled with 0.5 ml of water and a cotton plug into the control box. We added scents 15 min to 1 hour prior to commencement of a trial. We applied fur treatment to boxes by swiping a piece of fur on a wooden block, followed by placing the fur on the block for 15 min. We then placed the block in the assigned nest box and placed an untreated wooden block in the control box. Treatment of the blocks occurred 15 min to 1 hour before the squirrel was released and the trial began. We individually assigned each block to a scent. We repeatedly used control blocks except in the flying squirrel fur trials. We used the control blocks for this scent only once. To apply snake scent to nest boxes, we placed a live snake in the box for 15 min and then removed it  $< 1$  hour before the squirrel was released. The control box used for comparison to the snake-scented box had no scent applied.

The presentation of each scent to a squirrel constituted a trial. Trials occurred at night, during the active period for the squirrels. Trials started  $> 30$  min after sunset. We conducted trials in 3 trial pens, each  $0.5 \times 0.5 \times 0.5$  m. We attached two nest boxes to each trial pen (1 treatment, 1 control). We modified the nest box design from Sonenshine et al. (1973). The interior dimensions were  $33 \times 10 \times 11$  cm, and each had a 4.5-cm entrance hole. We placed a

squirrel into a release box ( $14 \times 6 \times 11$  cm) in the trial pen and allowed it to acclimate 10 min in darkness before we remotely opened the box. Once we released the squirrel, we monitored it for 3 hrs using a time-lapse video monitor (Pietz and Granfors 2000). We provided food and water ad libidum. We randomly determined the position of the treatment box (left or right side) and the trial pen used. We assigned nest boxes to specific scent treatments and used them for that scent anywhere from 1–22 times. While it is possible that repeated exposure to the scents may have increased the odor strength, using a unique box for each trial was not feasible due to financial constraints. We also used these boxes as a control as long as fur and urine samples never made contact with the box. If the cotton plug remained in place, we determined there was no contact between the urine sample and the box. We visually inspected for any fur in the box. While it would have been best to only use boxes once, financial constraints made this unfeasible. We treated all boxes except for the flying squirrel scent controls with flying squirrel scent by placing them in the holding pen and allowing captive squirrels to use them. We never placed the control boxes for the flying squirrel scent in the holding pen and only used them between 1 and 3 times to minimize incidental squirrel scent application. All boxes had  $\geq 1$  night without use before we used them as a control. The squirrels had  $\geq 1$  night off between trials to prevent the subjects' reactions from being affected by the previous trial (washout period). This study occurred from 1 September 2002–1 June 2003

Overall, there were 30 squirrels in the mammalian predator test, 30 in the squirrel test, and 22 in the snake test. The snake test had to be cancelled early due to health considerations in the captive snakes. We videotaped and examined 942 hours of flying squirrel behavior. For each subject we recorded which box it entered first, its reluctance to enter the box, the proportion of time it spent in each box, and the box it selected as its final roosting site. We defined reluctance to enter as the amount of time the subject spent between discovery of the box entrance hole and its first complete entry into the box. We corrected percent time spent in each box to include only time spent once both boxes were discovered. We did not include periods in the box  $\leq 5$  sec in the calculation for percent time in box. The final roosting site was the nest box that the squirrel occupied in the following morning. The sample size ( $n = 15$ – $26$ , depending on scent) was smaller for analyzing final roosting site selected because  $> 1$  trial was sometimes conducted per cage in a single night.

We used Wilcoxon signed-rank tests (Zar 1999) to determine if the difference between the treatment boxes and their paired control boxes were significantly different ( $P \leq 0.05$ ) regarding percent time in box and reluctance to enter. Data from each scent were analyzed separately. We used a  $\chi^2$  test (Zar 1999) to determine if the first box entered and the nest box chosen as the final roost site for each trial differed from expectation (1:1). We also ran an analysis of variance on ranked data (Kruskal-Wallis test, Zar 1999) to compare the difference in percent time in each box among the effective scents ( $P \leq 0.05$ ) and to see if any one scent was a better deterrent than any other.

## Results

For all squirrel scents, there was no difference between treatment and control boxes in terms of which box the subject entered first

**Table 1.** Mean percent of the time that southern flying squirrels entered nest boxes treated with animal scent instead of paired unscented boxes (control) at the Joseph W. Jones Ecological Research Center, Georgia, USA, from September 2002 to June 2003 and the results of a  $\chi^2$  test on whether selection matched availability (50%).

Scent	Treatment (%)	$\chi^2$	P-value
All squirrels	59.2	4.03	0.04
Flying squirrel fur	53.3	0.13	0.72
Flying squirrel urine	62.1	1.69	0.19
Fox squirrel fur	63.7	2.13	0.14
Gray squirrel fur	56.7	0.53	0.47
All mammalian predators	49.0	0.06	0.80
Bobcat fur	48.3	0.04	0.85
Bobcat urine	40.0	1.20	0.27
Raccoon fur	42.9	0.57	0.45
Raccoon urine	56.7	0.53	0.47
Red fox urine	56.7	0.53	0.47
All snakes	27.3	9.09	<0.01
Corn snake	31.8	2.91	0.09
King snake	22.7	6.55	0.01

(Table 1). There was also no difference in reluctance to enter treatment and control boxes for any squirrel scent (Table 2). There was no significant difference in use of flying-squirrel or gray-squirrel scented boxes and controls (Table 3). They spent less time in fox-squirrel scented boxes than control boxes. Also, when we grouped squirrel scents by interspecifics and conspecifics, flying squirrels spent less time in interspecific-scented boxes than the paired control boxes ( $S = 284.5$ ,  $P = 0.04$ ). Flying squirrels chose gray-squirrel scented boxes as final roosting site less than expected by chance (Table 4).

For all mammalian predator scents, there was no difference between treatment and control boxes in terms of which box the flying squirrel entered first (Table 1). Subjects entered mammalian predator-scented boxes and control boxes with equal speed (Table 2). Squirrels spent less time in bobcat-fur, red-fox-urine, and

**Table 3.** Mean percent time southern flying squirrels spent in boxes treated with animal scent and their paired untreated boxes (control) at the Joseph W. Jones Ecological Research Center, Georgia, USA, from September 2002 to June 2003 and the results of the Wilcoxon signed-rank test on whether the difference between the treatment boxes and their control boxes was significantly different from zero.

Scent	Treatment (%)	Control (%)	S-statistic	P-value
All squirrels	30.5	34.6	311.0	0.41
Flying squirrel fur	38.6	33.4	-26.5	0.59
Flying squirrel urine	32.0	26.9	-21.5	0.65
Fox squirrel fur	23.6	42.4	103.5	0.03
Gray squirrel fur	27.7	35.4	43.0	0.39
All mammalian predators	17.9	48.1	3,105.0	<0.0001
Bobcat fur	14.1	54.9	149.5	<0.001
Bobcat urine	24.8	39.4	73.5	0.13
Raccoon fur	11.6	54.1	147.0	<0.001
Raccoon urine	22.8	40.5	85.0	0.08
Red fox urine	16.0	52.4	166.5	<0.001
All snakes	11.5	50.5	380.0	<0.0001
Corn snake	15.0	45.3	79.5	0.01
King snake	8.3	55.0	113.5	<0.0001

**Table 2.** Mean reluctance to enter (in min) shown by southern flying squirrels for boxes treated with animal scent and their paired unscented boxes (control) at the Joseph W. Jones Ecological Research Center, Georgia, USA, from September 2002 to June 2003 and the results of a Wilcoxon signed-rank test on whether the difference between the treatment boxes and their control boxes was significantly different from zero.

Scent	Treatment (min)	Control (min)	S-statistic	P-value
All squirrels	4.50	8.93	677.0	0.06
Flying squirrel fur	7.78	6.85	29.5	0.53
Flying squirrel urine	1.70	11.88	63.0	0.18
Fox squirrel fur	2.92	4.29	82.0	0.08
Gray squirrel fur	5.51	12.77	15.5	0.74
All mammalian predators	3.55	3.58	-454.5	0.35
Bobcat fur	5.10	3.40	-40.5	0.37
Bobcat urine	3.11	4.47	-19.0	0.66
Raccoon fur	4.99	1.09	-51.0	0.25
Raccoon urine	2.52	2.27	-7.5	0.87
Red fox urine	2.21	6.50	19.0	0.70
All snakes	20.53	3.26	-298.0	<0.0001
Corn snake	6.34	1.49	-51.5	0.02
King snake	33.23	4.81	-113.5	<0.0001

raccoon-fur scented boxes than in control boxes (Table 3). The amount of time spent in bobcat- and raccoon-urine scented boxes was not different (Table 3) from the time spent in control boxes. Squirrels selected boxes with red-fox-urine and raccoon-fur scent as roost sites less often than would be expected by chance (Table 4). When we combined and separated raccoon and bobcat scents into fur and urine groupings, flying squirrels chose fur-scented boxes as roosts only 16% of the time ( $\chi^2 = 21.4$ ,  $P < 0.0001$ ), while urine-scented boxes were selected no differently from random.

King snake boxes were entered significantly less often (23%) than the paired control boxes (Table 1). Also, corn and king snake treatments caused squirrels to be significantly more hesitant to enter the treatment box than the control box (Table 2). Squirrels used both snake scented boxes significantly less than the control boxes (Table 3). Boxes with corn snake scent were entered last less than would be expected by chance (Table 4).

**Table 4.** Mean percent of the time that southern flying squirrels selected nest boxes treated with animal scent as the final roosting site instead of the paired untreated box (control) at the Joseph W. Jones Ecological Research Center, Georgia, USA, from September 2002 to June 2003 and the results of a  $\chi^2$  test on whether selection matched availability (50%).

Scent	Treatment (%)	$\chi^2$	P-value
All squirrels	59.2	4.03	0.05
Flying squirrel fur	58.8	0.53	0.47
Flying squirrel urine	60.0	0.60	0.44
Fox squirrel fur	46.7	0.07	0.80
Gray squirrel fur	23.5	4.77	0.03
All mammalian predators	49.0	0.06	0.80
Bobcat fur	31.8	2.91	0.09
Bobcat urine	45.5	0.18	0.67
Raccoon fur	0.0	0.00	<0.0001
Raccoon urine	39.1	1.09	0.30
Red fox urine	11.5	15.39	<0.0001
All snakes	27.3	9.09	<0.01
Corn snake	18.8	6.25	0.01
King snake	26.7	3.27	0.07

## Discussion

We predicted that squirrel scent should increase nest box use by flying squirrels because this scent should indicate a potentially safe roost site. Furthermore, flying squirrels are a social species that roost in large aggregations (up to 25 individuals); thus, roost site competition with conspecifics is minimal (Stojeba 1978, Stone 1993, Layne and Raymond 1994). However, our results indicated that flying squirrel scent had no effect on use of nest boxes by southern flying squirrels. Squirrel scent may not indicate a reduced risk of predation to other flying squirrels.

Flying squirrels showed no preference for entering gray- and fox-squirrel scented boxes; they spent less time in fox-squirrel scented boxes, and usually did not select gray-squirrel scented boxes as roosting sites. Because squirrel scent should indicate a reduced predation risk, this result was probably due to risk of displacement. Both fox squirrels and gray squirrels are much larger than flying squirrels and may be able to use aggression to displace them from a roosting site. Flying squirrels that are displaced from roosting cavities face an increased predation risk because they would be exposed during what is typically their inactive period. Because of this cost, flying squirrels may reduce the risk of displacement by avoiding roosting sites inhabited by gray squirrels or fox squirrels. This may be why squirrels avoided nest boxes that smell like these interspecifics in both this and other studies (Heidt 1977, Stojeba 1978, Doby 1984).

Flying squirrels spent less time in nest boxes containing any of the mammalian predator scents and rarely selected them as roosting sites. Red foxes, raccoons, and bobcats all are potential predators of flying squirrels (Dolan and Carter 1977). Of those, raccoons probably are the most likely to depredate a flying squirrel while in a nest box or cavity because they would have an easier time gaining access (Barkalow and Soots 1965, Muul 1968). However, raccoon scent was no more effective than the other predator species at reducing flying squirrel use of nest boxes. Squirrels may only recognize mammalian predator scent and not have the ability to differentiate species. Fur was more effective than urine at reducing use. This could be because fur is more indicative of animal presence in a cavity.

Squirrels avoided nest boxes containing the scent of corn and king snakes. Snakes are potential predators on flying squirrels, and entering a box containing a snake could be dangerous due to the risk of predation (Dolan and Carter 1977). Of the 2 species we tested, corn snakes are the better climbers and would more likely occur in a nest box or roosting cavity (Phillips and Gault 1997). In a concurrent field study at Ichauway, we found 4 corn snakes, but no king snakes, in nest boxes and tree cavities (Borgo, unpublished data).

### **Predator Odors as Flying Squirrel Repellents**

The potential use of predator scent to reduce wildlife damage has been investigated in many studies. Many mammals reduce feeding when confronted with predator odor from fecal matter, scent glands, and urine (Dickman and Doncaster 1984, Sullivan 1986). In studies that tested both urine and fecal material reported that the former was a more effective deterrent (Dickman and Doncaster 1984, Sullivan 1986). In our study we found that scent from fur was more effective than urine in reducing flying squirrel

use of nest boxes. Other repellent studies have not compared the effectiveness of fur with urine of the same species, so we cannot compare our results to others. However, our results indicated that fur has the potential to be a more effective deterrent.

Our study and others (Dickman and Doncaster 1984, Melchior and Leslie 1985, Merckens et al. 1991) have shown that predator odors are effective as repellents, but their level of effectiveness depended upon the species of predator from which the scent came. Banks (1998) and Herman and Valone (2000) reported that the strongest aversive responses occurred when both the target species and predator scent used were sympatric. All predator species included in this study could be found on site.

The activity patterns of the predator species whose scent is being used also may affect results. Urination and defecation patterns may be more representative of space use in some species than in others (Macdonald 1980, Dickman and Doncaster 1984). Because of these patterns, the scent of fox urine or scat may be more indicative of an elevated predation risk (Macdonald 1980, Dickman and Doncaster 1984). Bobcats and raccoons use latrines, so prey come across their scent less frequently, and their scent may not indicate a higher level of risk (Dickman 1992). This may be the reason that red fox urine was more effective than raccoon and bobcat urine.

Wildlife managers who seek to use predator odors to repel wildlife from structures will likely be unsuccessful unless alternate shelters are available for the displaced animals to use (Conover 2002). Merckens et al. (1991) showed that when using predator scents as deterrents to foraging, scent effectiveness was dependent upon the availability of alternative patches of equal or better quality. We also observed this in a separate experiment where squirrels were only provided a single nest box. In this experiment the subject was found in the morning in the treated box regardless of whether the box contained a predator scent (Borgo, unpublished data).

While the snake scents, raccoon fur, and red fox urine were all effective deterrents of flying squirrels for at least 2 of the dependent variables, red fox urine would be the most cost efficient and easily applied deterrent. This is because both snake musk and fur are hard to acquire in bulk, and fur application could be difficult or time consuming on a wide scale. In contrast, red fox urine is effective, affordable, and easily obtained from any of several reputable dealers. Furthermore, application of urine would not be that difficult as it can be sprayed where needed.

### **Management Implications**

The southern flying squirrel is the main competitor for cavities used by red-cockaded woodpeckers, and flying squirrel presence in a cavity reduces reproduction of this endangered bird (Dennis 1971, Harlow and Lennartz 1983, Loeb 1993, Loeb and Hooper 1997). It may be possible to stop flying squirrels from usurping red-cockaded woodpecker cavities by spraying the cavities with predator scents. This method appears promising because birds do not rely on olfaction as heavily for predator detection as mammals do and this study has shown that flying squirrels avoid cavities that smell of predators. Before this method can be used as a management technique, field trials are necessary. Our observations also suggest that the effectiveness of this technique will probably

be enhanced if alternate roosting cavities (e.g., nest boxes) are provided nearby for the displaced flying squirrels. Loeb and Hooper (1997) found that while occupation of red-cockaded woodpecker cavities by flying squirrels reduced reproductive potential of the bird, occupation of nest boxes within the cluster area did not impact reproduction. Also, scent deterrents may be less effective in the field due to the problem of habituation. Over time, experiencing the scent without negative consequences could reduce the squirrels' avoidance response to the scent. This result can be avoided by continuing to remove those animals that ignore the scent and occupy cavities which have been treated with a predator scent.

Future studies are necessary to determine the effectiveness of scent deterrents and the frequency of scent applications under field conditions. We also must determine the threshold where

habituation supercedes the effectiveness of deterrents. Further studies should address the following: 1) frequency of cavity exploration by flying squirrels; and 2) the likelihood of cavity entry, regardless of predator odor, if there is a food reward (e.g. bird eggs). This information would provide additional evidence of the potential use of predator odors as scent deterrents for flying squirrel management.

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**Jennifer (Jen) S. Borgo** (photo) currently is a Ph.D. student in the Department of Forest, Range, and Wildlife Sciences at Utah State University, where she also obtained her M.S. degree. She earned a B.S. at Auburn University in zoology. She is a member of the Jack H. Berryman Institute. Her research interests include human–wildlife conflicts, endangered species management, and interspecific interactions. **L. Mike Conner** is the Associate Scientist for Wildlife Ecology at the Joseph W. Jones Ecological Research Center in Newton, Georgia. **Michael R. Conover** is the director of the Jack H. Berryman Institute and professor in the Department of Forest, Range, and Wildlife Sciences at Utah State University.

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