FINAL REPORT: NEST PREDATOR HABITAT USE AND AN EVALUATION OF SURVEY TECHNIQUES AT THE RADFORD ARMY AMMUNITION PLANT

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Table of Contents

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LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

The decline of grassland birds has been dramatic in Virginia (Askins 1993) and elsewhere. Much research effort has focused on factors relating to nesting success to explain this decrease (Ricklefs 1969). Nesting success has been linked to landscape factors at both the local (Gehring and Swihart 2002) and landscape levels (Sovada *et al*. 2000, Phillips *et al*. 2003). Although there is some ongoing debate as to how important landscape factors, such as edge, are to nesting success (Lahti 2001, Chalfoun *et al*. 2002), most authors agree that habitat and landscape factors can have an effect on the hunting activity and efficiency of nest predators (Gehring and Swihart 2002, Kuehl and Clark 2002).

Predator activity patterns have been tied directly to nesting success by several researchers (Sovada *et al*. 2000, Gehring and Swihart 2002, Kuehl and Clark 2002, Phillips *et al*. 2003). This affect may be the result of opportunistic predation by predators spending a disproportionate amount of time in one type of habitat over another. Similarly, if opportunistic predators predate a grassland bird nest while actively searching for other primary prey, then the probability of nest predation increases in locations frequented by predator species.

In this project, we investigated techniques to assess habitat use patterns of important grassland bird predators. Furthermore, we examined habitat relationships of the predators of ground nesting birds in order to better understand how nest placement is related to nesting success.

The main objectives of this investigation were to:

1) Develop methods for assessing nest predator distribution and habitat use, and indices of predator abundance at the Radford Army Ammunitions Plant (RAAP) in southwestern Virginia. Focal predator species included red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), striped skunk (*Mephites mephites*), raccoon (*Procyon lotor*), Virginia opossum (*Didelpis marsupalia*) and domestic cat (*Felis domesticus*),

2) Identify habitat variables associated with predator habitat use at the RAAP, and

3) Develop predictions for grassland bird nesting success as a function of nest predator habitat use at the RAAP.

STUDY AREA

The Radford Army Ammunition Plant consists of two geographically separate facilities in southwestern Virginia: the Main Manufacturing Unit (~1660 hectares) 8 kilometers northeast of Radford, VA and the 1100 hectare New River Unit, 10 kilometers west of Dublin, VA in Pulaski county (Figure 1). Both facilities are found in the Appalachian Mountains. This study was conducted entirely at the New River Unit. The New River Unit is ecologically unique from the surrounding landscape in that it is composed of large grasslands with small woodlands and forest patches (Figure 2). In contrast, the surrounding landscape is largely a patchwork of mixed-use farmland. See VDGIF (1999) for more information and a complete description of the ecological communities at the facility.

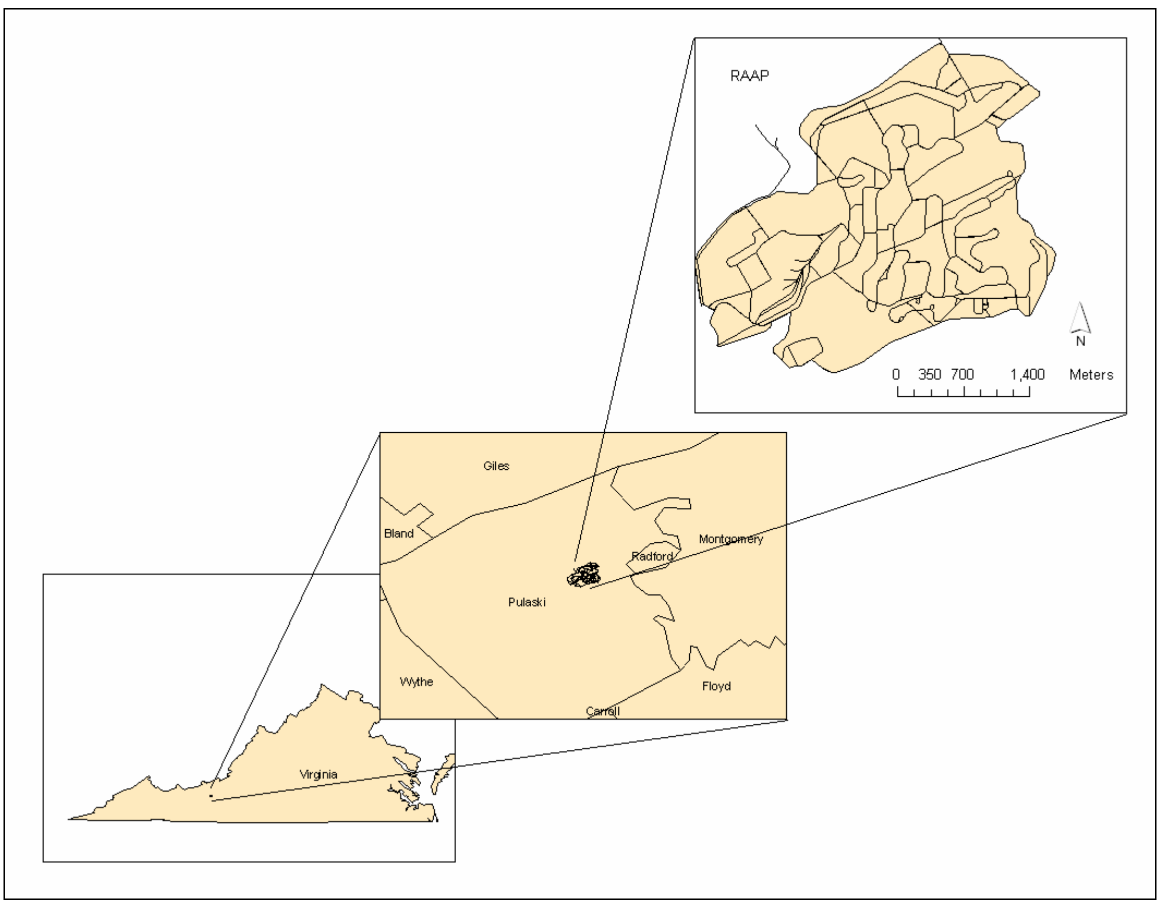

Figure 1. Location of the Radford Army Ammunition Plant (RAAP), New River Unit.

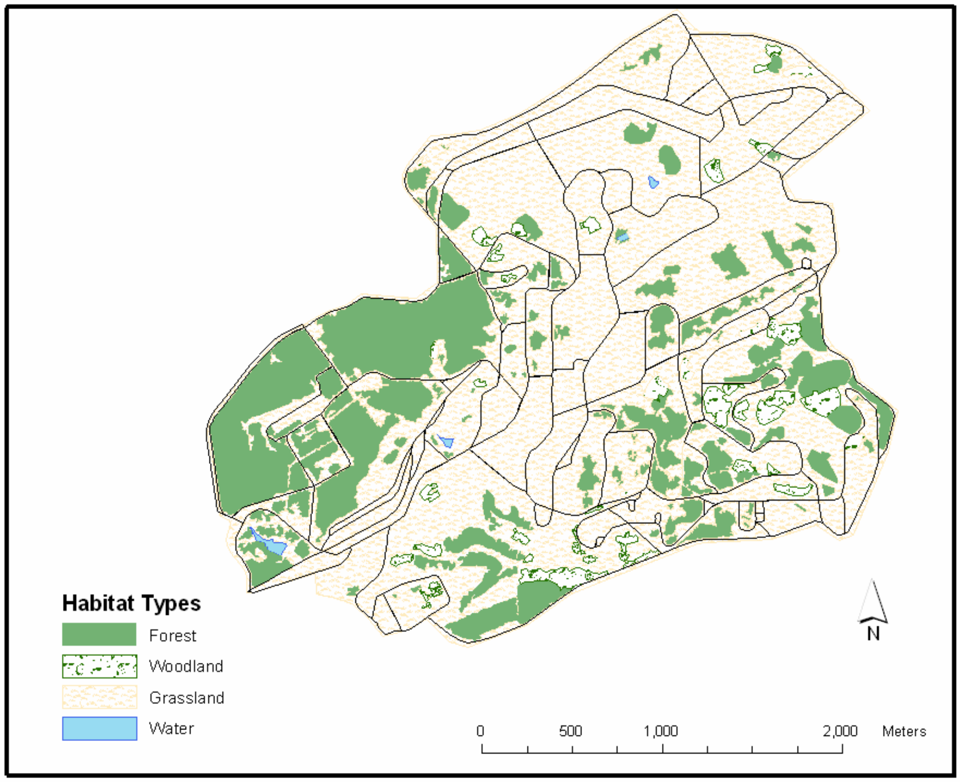

Figure 2. Generalized habitat types at the Radford Army Ammunition Plant, New River Unit. This figure modified from VDGIF 1999 using digital aerial photos (circa 1999).

RELATIONHSHIPS BETWEEN HABITAT CHARACTERISTICS AND NEST PREDATOR HABITAT USE

Methods

To assess the relationships between predator habitat use and habitat features, we used 2 techniques – scent/track stations and scent/camera stations. These methods, or variations thereof, have been used successfully to survey carnivores in other research studies (Nottingham *et al*. 1989, Diefenbach *et al*. 1994, Smith *et al*. 1994, Danielson *et al*. 1996, Travaini *et al*. 1996, Foresman and Pearson 1998, Sargeant *et al*. 1998, Cutler and Swann 1999, Warrick and Harris 2001, Wilson and Delahay 2001, York *et al*. 2001, Harrison *et al*. 2002, Moruzzi *et al*. 2002, Schauster *et al*. 2002, Loukmas *et al*. 2003, Sargeant *et al*. 2003, Thompson and Burhans 2003).

To establish locations for these and other survey stations, we used ArcGIS to create a random distribution of 113 geographic points. Each point represented a potential location for the placement of a survey station. The minimum distance between points was 225 m. One-hundred thirteen points was the maximum of locations given our minimum spacing criteria. Survey locations were chosen regardless of habitat type. Locations that fell on roads or within 25 m of magazines were moved to the nearest vegetated area away from the road or bunker.

Specific methods for each sampling technique are presented in the appropriate section below.

Vegetation Sampling and Analysis

At each survey location, we established five 1 m^2 sampling subplots to assess vegetation structure. One subplot was randomly placed immediately adjacent to the survey location by spinning a compass dial. The remaining 4 subplots were placed 5 m away in each of the 4 cardinal directions (N, S, E, W). A guide fashioned from PVC tubing was used to form a square and to delineate the sampling area.

Within each subplot, we estimated the percent cover of graminoids, forbs, shrubs, trees (conifer and hardwood), litter, bare (ground level only) at each of 3 height classes: 0-1 m, 1-2 m, and >2 m using the Daubenmire cover scale (Daubenmire 1959). The cover classes we used were defined as 0-5%, 5-25%, 25-50%, 50-75%, 75-95%, or 95-100%. Additionally, we established a 1/10 acre (11.3 m radius) tree inventory at each plot. We counted all trees greater than 2 inches dbh and placed them in 2-inch size classes (i.e. 2-4”, 4-6”, etc.) by tree type (hardwood/conifer).

For statistical analysis, we used cover class midpoints and averaged the 5 subsamples at each location to obtain a single value for each plot at each height class. Likewise, we used the midpoint of each stem size class to calculate basal area. Thus, for pines in the 10-12” class, we calculated the basal area for 11 inch trees, etc. We chose to analyze and discuss forest metrics in English units rather than metric units for the convenience of professional foresters.

A list of these variables used in the analyses and appropriate metadata are found in Appendix 1.

Development of GIS Layers

We developed several base GIS layers by on-screen digitizing from existing digital aerial photos (circa 1999, exact date unknown) and converting the resulting vector products to ESRI shapefiles. We used this approach to develop layers describing roads and boundary fences, and to modify an existing habitat map originally produced by the Virginia Department of Game and Inland Fisheries (VDGIF 1999). We modified the VDGIF map because many smaller woodland and forest patches were not reliably and consistently delineated from grasslands and to improve the overall spatial accuracy of habitat boundaries. Our final product had a minimum mapping unit of approximately 0.25 ha. Habitat types are presented in Table 1 and follow National Vegetation Classification System physiognomic classes (The Nature Conservancy 1994).

We derived many other potentially important independent variables from those described above, such as distance to road, distance to forest, and distance to edge. A list of these variables and appropriate metadata is found in Appendix 2.

Table 1. Habitat types used in analyses. Habitat definitions follow National Vegetation Classification System physiognomic classes (The Nature Conservancy 1994).

Habitat Type
Deciduous Forest
Pine Forest
Mixed Forest
Deciduous Woodland
Pine Woodland
Mixed Woodland
Grassland

Scent/Track Stations

We established 60 randomly selected locations (from the original 113 points) for scent/track stations (Figure 3). Each station was prepared by clearing just enough vegetation to place a 1 m diameter circular plot. All vegetation, including grass and protruding roots etc., was removed, and a sand/mineral oil mixture (ratio: ~23 kilograms sand/1 liter mineral oil) was then sifted onto the ground, approximately 3-4 cm deep, allowing animal tracks to be recorded in the sand.

To 'activate' stations, we placed a cotton ball treated with 10 drops of either rabbit or pheasant scent (Cabela's© brand) as a mild attractant at each plot center. The cotton ball was enclosed in a small perforated plastic capsule (Tissue-Tek©) and placed approximately 0.2 m above the ground on a sturdy metal wire.

Because of especially high workload at the beginning of the study, we operated only 25 of the stations for the first 2 sampling periods. By the end of the study, all 60 stations were operated simultaneously. Stations were operated between July 15 and August 21, 2003. Stations were activated (i.e. baited with attractant) on Mondays and were revisited for 3 consecutive days to check for tracks. Each day, we replaced the cotton ball and replenished it with fresh scent and sifted fresh sand onto the plot to cover existing tracks. In this way, we knew that observed tracks were from the previous 24 hr period. If rain made tracks indecipherable, we disregarded that day's effort, re-baited the trap, and checked for another day, up to a maximum of 4 consecutive survey nights. Stations were not baited on Friday, Saturday or Sunday nights.

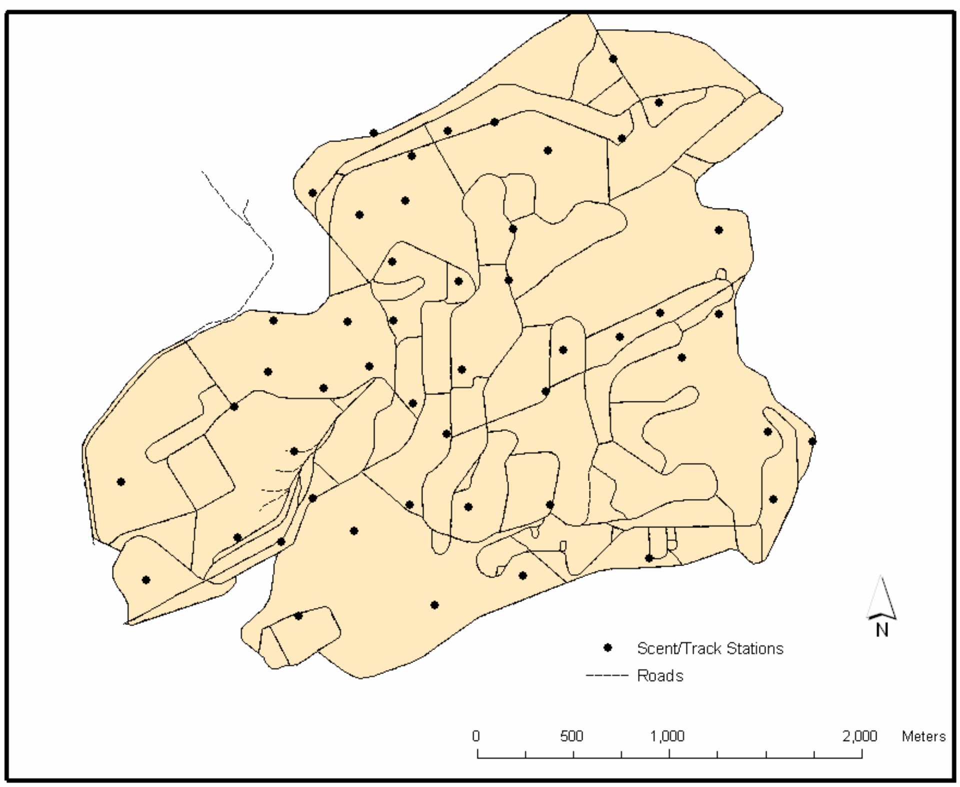

Figure 3. Distribution of scent/track stations at the RAAP.

Analyses

We employed logistic regression to identify variables associated with plot use – the dependant variable being tracks detected/not detected on any given day. We conducted this analysis independently for each target species with sufficient data ($\geq$10 detections); non-target species, such as deer and birds which regularly visited plots, were not considered. We assessed the relationships between habitat use and habitat and landscape characteristics using a two-stage approach. A two-stage approach was necessary because our statistical package (SAS) did not provide the ability to test (and control, if necessary) for potential temporal correlations between observations while simultaneously using a model selection procedure. Multiple observations at the same plot were essentially treated as repeated measurements, and our analysis needed to account for this. Therefore, we first used SAS PROC LOGISTIC with the forward stepwise selection procedure (Myers 1989) to select the subset of variables that provided the best fitting model. The candidate list of variables is presented in Appendix 3. For this step, we used a significance level of 0.10 for variable entry into the model and 0.05 for variable retention. Bait type was included as a categorical covariate in the variable list. Likewise, we included date and X and Y UTM (Universal Transverse Mercator) coordinates to help control for potential temporal and spatial autocorrelation, respectively. This procedure produced a model for each species.

Next, we assessed the importance of temporal autocorrelation among observations at the same location in the models produced above. To do this, we used SAS PROC GENMOD, which allows for the repeated measures analysis within a logistic model. For this analysis we used an unstructured correlation matrix in a repeated measures design. Sample SAS code is presented in Appendix 3.

Temporal correlation was not a problem in any of the models. Therefore, the results produced in step 1 are meaningful and we present and discuss those in this report.

Scent/Camera Stations

We placed scent/camera stations at 20 randomly chosen locations (from the original 113) (Figure 4), as described above for scent/track stations. Each station consisted of a CamTrakker® surveillance system, with an automatic camera and passive infrared motion detector system (hereafter camera), and a mild attractant, as described in Scent/Track Stations. Cameras were placed approximately 3.5 m from the attractant and were secured 1 m above ground to a metal fence post. Cameras were oriented so that an animal approaching the attractant would trip the camera and a picture would be taken. To reduce the number of exposures with the same animal, cameras were set so that a minimum of 10 minutes must have passed between successive photos. The date and time of the photo was automatically recorded on the film and later entered into a database for analysis. If necessary, we thinned vegetation between the camera and the attractant to allow an unobstructed view of the approaching animal.

Stations were operated in 2 arrays of 10 cameras (Figure 4). Arrays were operated alternately for 3 consecutive days. Array A was operated for two 3-day bouts beginning on 7/25 and 8/8, and Array B was operated beginning on 8/1 and 8/15.

<u>Analyses</u>

Because of the low sample sizes for target species, we performed no statistical testing from the results of this method (see appropriate results section).

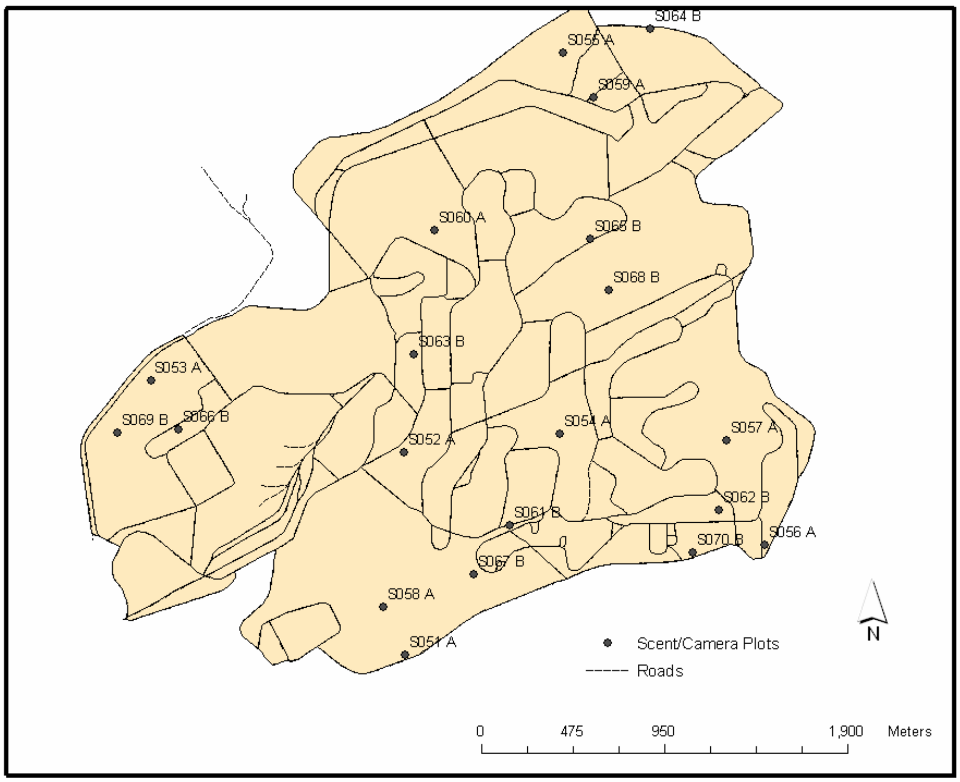

Figure 4. Distribution of scent/camera stations at the RAAP. Stations were operated in 2 arrays of 10 cameras. The letter after the plot number refers to the array in which the plot belongs.

Results

Scent/Track Stations

We successfully collected data from the scent/track stations on 12 days for a total of 480 trap days. Data was not collected on an additional 10 days due to rain, which washed away sand and/or obscured tracks. A summary of effort is presented in Table 2.

Animals that visited the plots left tracks that were easily identified. Only on a few occasions (7) could tracks not be confidently identified. On average, 52% (248 of 480 trap days) of plots received visits of some kind since the last check of that trap – 1 day before. Target species detected were: domestic cat, gray fox, red fox, stripped skunk, raccoon, Virginia opossum, snake spp. Non-target species detected included woodchuck, deer, unidentified small mammal (i.e. squirrel), turtle, and wild turkey. Deer was the most common mammal species detected (68/480), followed by unidentified small mammal (i.e. squirrel; 53/480), raccoon (22/480), and woodchuck (16/480). Summary information is presented in Table 3.

We created logistic models to assess the relationship between plot use and habitat variables for 3 target species: raccoon, Virginia opossum, and striped skunk. Other target species were detected too infrequently to identify relationships. Raccoon plot use was inversely related to D2_fence (distance to fence) and D2for_d (distance to deciduous forest), and positively related m_forb (percent cover of forbs ≥1 m in height). Virginia opossum plot use was inversely related to D2_fence and positively related to ba_hwdgt10 (basal area of hardwoods ≥10 in) and gc_woody (percent woody cover <1 m in height). No habitat or landscape variables were significantly related to striped skunk plot use. Parameter estimates for raccoon and opossum models are presented in Table 4 and Table 5.

Temporal correlations between observations were weak and as a result, parameter estimates from PROC LOGISTIC and PROC GENMOD were nearly identical. Likewise, we found no evidence of spatial autocorrelation between plots.

Scent/Camera Stations

Stations were operated for a total of 120 trap days. Seventeen exposures revealed animals, but the only target species detected was raccoon. Excluding duplicate species on the same plot/day, deer were detected on 10 of 120 (0.088) plot days, wild turkey on 1 of 120 (0.008) plot days, and raccoons on 2 of 120 (0.017) plot days (Table 6).

One hundred seventeen exposures had no identifiable animal present. Presumably these exposures were triggered by moving branches and grass, passing automobiles, shadows, or equipment failure.

Table 2. Summary of effort for scent/track stations. "# Plots" is the number of plots operated on the corresponding date.

Date	# Plots
7/16/2003	25
7/17/2003	25
7/18/2003	25
7/22/2003	25
7/23/2003	Rain
7/24/2003	25
7/25/2003	25
7/29/2003	Rain
7/30/2003	Rain
7/31/2003	30
8/1/2003	Rain
8/5/2003	Rain
8/6/2003	Rain
8/7/2003	Rain
8/8/2003	Rain
8/12/2003	60
8/13/2003	Rain
8/14/2003	60
8/15/2003	Rain
8/19/2003	60
8/20/2003	60
8/21/2003	60

Table 3. Scent/track station detection rates (per day) and the number of detections by species. N=480

Species	Detection Rate	Times Detected
Unidentified Bird	0.17	80
Deer	0.14	68
Unidentified Small Mammal	0.11	53
Raccoon	0.05	22
Woodchuck	0.03	16
Striped Skunk	0.03	12
Virginia Opossum	0.02	10
Eastern Cottontail	0.02	9
Unknown	0.02	8
Wild Turkey	0.02	8
Domestic Cat	0.01	7
Gray Fox	0.01	6
Unidentified Snake	0.01	6
Red Fox	0.01	3

Table 4. Relationships between habitat characteristics and likelihood of detection at scent/track stations for raccoon. The best model was chosen using logistic regression with the stepwise selection procedure (p<0.1 for entry, p<0.05 for retention). Variables are defined in Appendices 1 and 2.

Variable	Estimate	St Error	Chi-Square	P-value
m_forb	0.038	0.012	10.353	0.001
D2for_d	-0.002	0.001	4.661	0.031
D2_fence	-0.003	0.001	6.263	0.012

Model fitting statistics: n = 478, X^2 = 22.2, df = 3, P < 0.0001
Percent concordant: 74.3, percent disconcordant: 22.5

Table 5. Relationships between habitat characteristics and likelihood of detection at scent/track stations for Virginia opossum. The best model was chosen using logistic regression with the stepwise selection procedure (p<0.1 for entry, p<0.05 for retention). Variables are defined in Appendices 1 and 2.

Variable	Estimate	St Error	Chi-Square	P-value
D2_fence	-0.014	0.005	7.239	0.007
ba_hwdgt10	0.056	0.023	6.137	0.013
gc_woody	0.046	0.017	7.854	0.005

Model fitting statistics: n = 478, X^2 = 35.09, df = 3, P < 0.0001
Percent concordant: 93.4, percent disconcordant: 5.3

Table 6. Species and the number of days detected by plot for scent/camera stations. Plots without detections are not shown. Twenty plots were operated for 6 days each, for a total of 120 trap-days.

Plot	Wild Turkey	Deer	Raccoon
S051			
S052		1	
S053		4	
S055			2
S063		2	
S065		2	
S066		1	
S067	1		
Total	1	10	2

Discussion

Species Models

Scent/camera stations were ineffective at detecting target species. As a result, logistic models were built using only data from scent/track stations. Because of the low number of detections, we were able to create logistic models for only 3 target species – raccoon, Virginia opossum and striped skunk. We found no significant relationships between striped skunk habitat use and habitat or landscape features. However, raccoon and opossum habitat use was related to both habitat and landscape features, and one landscape characteristic was related to both species – proximity to edge. This relationship is made evident by two significant variables, distance to deciduous forest edge and distance to fence. Both species' habitat use was inversely correlated with distance to fence (i.e. plots closer to the fence were more likely to be visited by these species than plots further away), and raccoon habitat use was inversely related to distance to deciduous forest edge. While it is possible that animals are not responding to the fence *per se*, but to the mowed habitat adjacent to the fence, we feel this scenario is unlikely. We believe proximity to fence is an edge effect, rather than a habitat/vegetation effect, because habitat use was not related to any other habitat/vegetation variables indicative of this type of habitat.

Proximity to edge may be important in a number of ways. First, the travel-lane hypothesis states that animals may use edges as travel corridors(Bollinger and Peak 1995, Fenske-Crawfored and Niemi 1997). In this scenario, predators prefer to travel along edges to get from location A to location B. This concept has received much attention and research but lacks strong supporting evidence (Lariviere 2003). Second, it is possible that predators prefer to forage in and near edge habitats because of an increased foraging efficiency experienced there. Finally, predator abundance or diversity may be greater in the habitat provided by edges. See Lariviere (2003) for a more detailed discussion on edge effects and predator movements.

Why raccoon and opossum habitat use was related to edge features is beyond the scope of this project. Regardless of the mechanism, if this relationship holds true, then bird nests located near edge may be more susceptible to depredation than those further away. This claim is supported by Pasitschniak-Arts (1998), who demonstrated that greater use of edges by skunks was related to decreased success for duck nests in Saskatchewan.

Raccoon habitat use was also positively related to the percent forb cover in the 1-2 m height class. This corresponds closely with percent cover of *Verbesina alternifolia* (wingstem) and *Verbesina occidentalis* (stickweed). No other forb species typically achieved heights >1 m in the study area. Both of these plants are commonly found in pastures, hay fields, fencerows, roadsides, and rights-of-way. It is unclear at this point whether raccoon activity is associated with these plants because of the cover or other resources they provide or because they are associated with some other unmeasured landscape feature.

In addition to edge features, Virginia opossum habitat use was positively related to forested and wooded areas, especially with large trees ($\geq$10 in dbh) and with a shrubby groundcover. That these are the features typically associated with opossum habitat illustrates that our modeling effort was successful. However, opossums exhibit a wide range of ecological tolerance for habitat and are known to inhabit fields and farmland as well as forests (Burt and Grossenheider 1980), and thus bird nests placed in grasslands are also at risk to predation. Nevertheless, these results suggest that nests placed in proximity to wooded areas and edges may be at greater risk of predation by opossums.

At the RAAP, the areas with the greatest amount of edge habitat are those in the south and southeast, where there is a mix of small woodlands intermixed with grasslands. However, although we were able to identify variables associated with predator habitat use that suggest edge habitats result in greater nest depredation rates, these relationships were weak. As a result, we could not confidently create large-scale spatial models identifying high risk areas for nesting grassland birds.

Scent/track Station Performance

Scent/track stations were effective at detecting mammal presence. This was illustrated by the results of the evaluation plots and by its relative success compared to scent/camera plots. This method was the only method that produced enough data in this study to build logistic models describing habitat features associated with predator use. Furthermore, all target species – raccoon, red fox, gray fox, Virginia opossum, stripe skunk, and domestic cat – were detected using this method. Once scent/track plots are established, it only takes a few minutes to check a trap for tracks, refresh the 'bait', and re-sift sand for the following survey day. Most field time is spent traveling to and from plots across the landscape. Once observers became familiar with field protocol and the location of plots, they were able to operate up to 60 traps per day. In addition, the method requires little post-processing effort, such as film development (camera traps) or hair identification (hair snares). Only on a few occasions did observers need to spend time outside of the typical workday to identify digital photos of previously unidentified tracks.

This method, however, is not without its drawbacks. Rain readily obscures tracks and sometimes even washes away sand, forcing reconstruction of the station the following day. In this study, rain was a major problem. For the scent/track stations, 10 of 22 survey days were discarded due to due rain. Rain affected the utility of this method in two ways. First, rain before an animal visited the station made the sand hard and crusty and less likely to record tracks. Second, rain after the tracks had been recorded tended to obscure the tracks. So, even a short downpour any time during the survey period could destroy an entire day's worth of effort. Plots under forested cover fair better than plots in the open.

The utility of scent/track stations decreased as activity at the plot increased. This was especially true when one species left multiple tracks or dug in the sand, thus obscuring the tracks of other species. This may have occurred on several occasions when raccoon tracks were so abundant that other tracks may have been destroyed, and at least on one occasion when a domestic cat dug in the sand.

Scent/Camera Station Performance

This method has great utility in that it easy to accomplish and requires little field work. Once plots are established cameras only need to be checked every few days to replace film, and species are readily identifiable from the photos. However, this method was not successful at detecting the target species identified for this study; raccoon was the only target species detected, and it was detected only at one plot. Perhaps this is because many of the target species in this study are small and were less likely to trigger an exposure than larger animals such as deer. Larger animals, e.g. deer, seem to have been readily detected using this method. We believe that this method, as applied here, severely underestimated the visitation rates of many or all of the target species (i.e., many visits went undetected). We base this assertion on the results of the scent/track stations, which used the same attractant, and had much greater success in detecting target species. Although possible, it is unlikely that differences in habitat around the scent/camera stations can alone explain the lack of predators detected by this method. Because this method was ineffective, we were unable to use the data to create models describing relationships between habitat use and habitat features.

The camera systems used in the part of the study were CamTrakker® units, which utilized a passive infrared motion detector system. These units differ from the active infrared motion detectors used in the TrailMaster® units described in the Evaluation Plots section below.

AN EVALUATION OF 3 SURVEY TECHNIQUES – EVALUATION PLOTS

Evaluation Plots

At 8 randomly selected locations (Figure 5), we established evaluation plots to examine the efficacy of a newly developed hair snare technique in relation to a modified camera trap and track station. Hair snares have been used successfully to detect mammal presence for a number of species (Pasitschniak-Arts and Messier 1995, Mills *et al*. 2002). However, to the best of our knowledge, all techniques have used a strong bait or attractant to lure animals to a distinct location where hair samples were collected, often from stakes protruding from the ground. We wanted to examine the possibility of using barbed wire over larger areas (50 m-100 m linear distance) to *passively* collect hair samples. To evaluate this potential technique, we undertook a pilot project to assess whether horizontal strands of barbed wire would collect hair samples from animals that traveled under, through or over the wire. If successful, this method could be used on a larger spatial scale.

At each survey location, we cleared just enough vegetation to place the trap. We then constructed a 2 x 2 m square grid with metal fence poles at each corner. Two strands of barbed wire were strung between the poles, as tight as possible, at heights of 10.2 cm and 25.4 cm above ground, forming a square array of barbed wire. At the center of the array, we placed a sand track station, as described above. On diagonal support poles, we mounted a TrailMaster® active infrared trail monitoring system, with the activation beam orientated horizontal and approximately 10-15 cm above the ground (Note: This monitoring system differs from the CamTrakker® units utilized for the scent/camera traps discussed above). The beam passed diagonally through the plot, directly over the sand track station. At the center of the plot, on a metal wire extending 0.1 m above ground, we placed a canned sardine as bait. Figure 6 illustrates the trap design.

Evaluation stations were operated between July 15 and August 21, 2003. Stations were activated (i.e. baited with attractant) on Mondays and were revisited for 3 consecutive days to check for tracks and hair and to replace film and/or bait, if necessary. Observers carefully examined the entire length of wire for hair and placed samples in marked coin envelopes for later identification. Likewise, the sand track circle was carefully examined for tracks. At the end of the study, under laboratory conditions, we used a high-powered microscope and references by Stains (1958) and Adorjan and Kolenosky (1969) to identify animal hair. Each day we replaced the sardine and sifted fresh sand onto the plot to cover existing tracks. In this way, we knew that tracks discovered were from the previous 24 hr period. If rain made tracks indecipherable, we disregarded that day's effort, re-baited the trap and checked for another day, for a maximum of 4 consecutive survey nights. Stations were not baited on Friday, Saturday or Sunday nights.

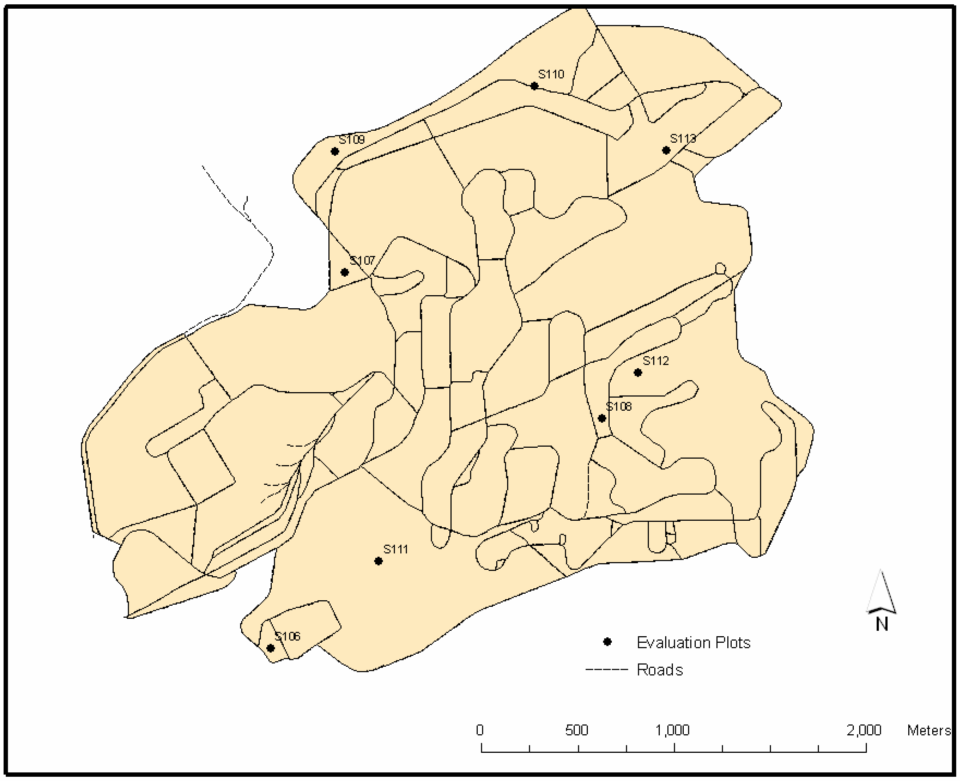

Figure 5. Distribution of 8 randomly located evaluation plots. Evaluation plots examined the efficacy of 3 sampling techniques – track stations, camera stations, and hair snares – used simultaneously.

Figure 6. Example evaluation plot. Evaluation plots examined the efficacy of 3 sampling techniques – track stations, camera stations, and hair snares – in the presence of each other.

Results

The evaluation plots were operated for a total of 124 trap nights, and we observed 111 known visitations (overall detection rate: 0.895). We calculated the number of known visitations by summing the number of hair, track, or photo observations and subtracting all instances where multiple techniques detected the species animal on the same night. Many of these visitations were from non-target animals such as birds and deer, so we omitted them from further analyses. The total number of visits by nest predators was 42 (0.339). An example photo is presented in Figure 7.

The camera and track methods detected 28 (25.2% of known visits) and 21 (18.9%) known visits from target species, respectively, while the hair snare captured just 5 (4.5%). These visits are recorded for all days where the evaluations plots were active.

Because rain severely affected the utility of the track method, we also examined only those days where rain did not affect our ability to detect tracks in the sand array. The total number of rain-free days was 59. On those days we detected 20 (34%) nest predator visitations with track circles, 11 (18.6%) visitations with the cameras, and 4 (6.8%) visits with the hair snares. Figure 8 illustrates detection efficiency by species and method for no-rain days. An instance where a visit was recorded with multiple observations was relatively rare. We detected a visit with all 3 methods only 2 times (1.6%). Examining only target species (rain was examined but determined to be not a factor), we observed only 8 (6.5%) instances of visits recorded by both tracks and photos. We observed no instances where track, photos, or hair detected on the same night resulted in disagreement with species identified.

We calculated the overall detection rate for each target species by dividing the total number of visits detected for the species by the total number of known visits for all species. The raccoon was the most commonly observed nest predator species (27 detections) followed by the striped skunk (12) and Virginia opossum (2). Raccoons were detected most often with photos (63% of observations) and tracks (59%) when all days are used. When we examine only those days were rain did not affect the track stations, we find that raccoons were detected most often by tracks (83%) followed by cameras (50%). We observed a similar increase in detection rate for tracks for striped skunk and Virginia opossum when we compared days with rain to days without. For the striped skunk, however, we observed a loss of 8 observations (75%) when rain days were omitted. Figure 9 illustrates how the utility of methods change with respect to rain.

Figure 7. Example photograph from evaluation site.

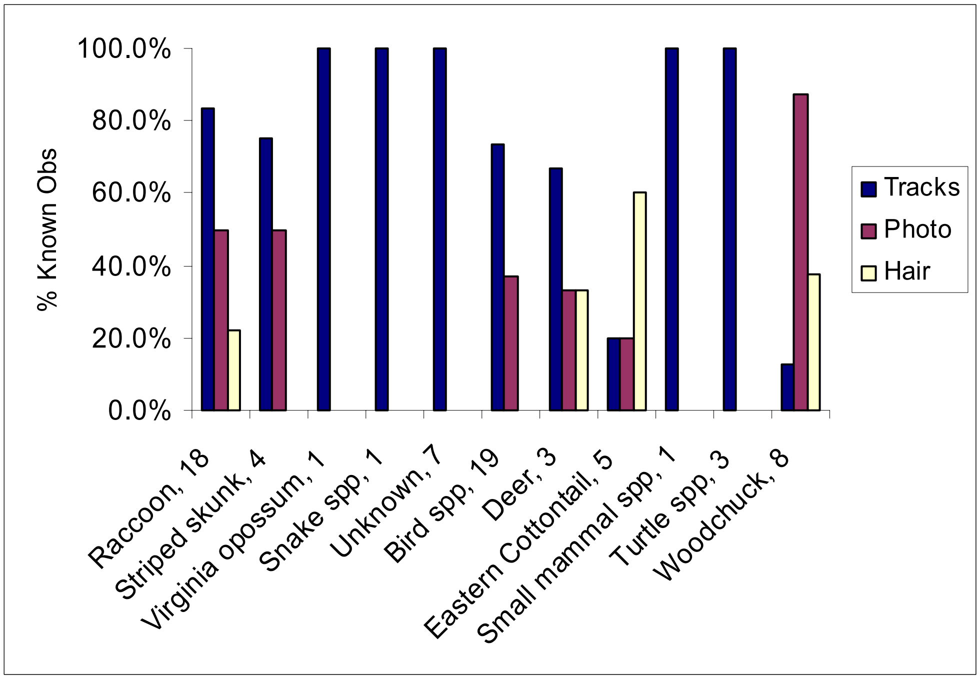

Figure 8. Percentage and number of known detections for the evaluation plots by method and species, rain days excluded. The value after the species name is the number of detections for that species. We calculated the number of known visitations by summing the number of hair, track, or photo observations and subtracting all instances where multiple techniques detected the species on the same night. Plots were operated for a total of 124 trap nights. There were 70 known visitations (rain days excluded; 56.5% of nights).

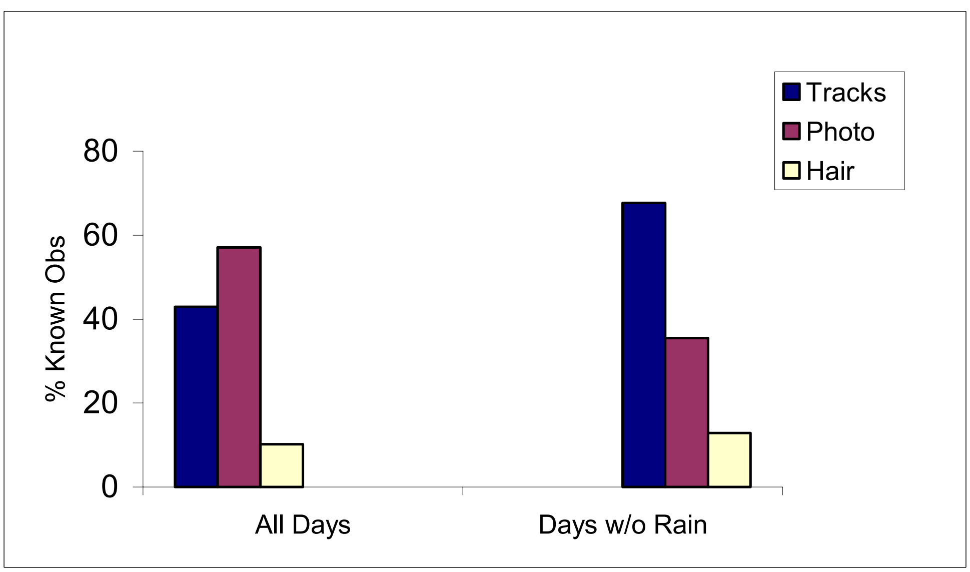

Figure 9. Percentage of known detections at evaluation plots by method and rain/non-rain days for mammalian nest predators (all species combined). We calculated the number of known visitations by summing the number of hair, track, or photo

observations and subtracting all instances where multiple techniques captured an animal on the same night

Discussion

The purpose of the evaluation plot study was to simultaneously compare the efficiency and accuracy of hair-snares, track circles (scent/track stations), and cameras (scent/camera stations) for identifying animals visiting the site. Ideally, each visit would have been captured by all 3 methods and each would be accurately identified to species. Through this effort, we determined that there are differences in the efficacy of each method for detecting potential mammalian nest predators on the RAAP. Although the number of samples is small, we feel that some useful information has been obtained.

It is apparent that no single method captures all the possible visits effectively. Although the sand track circles were effective at capturing many of the visits (68.0%), they were largely ineffective when rain fell over the trap period. The cameras were actually observed to decline in effectiveness when only no-rain days were analyzed; we attribute this decline to the loss of most skunk observations, 75% of which occurred during rainy evenings. This suggests that the skunks may be more active during rainy periods, and without the cameras, their visits to the evaluation plots would have gone undetected. Hair trapping was consistently lower than either of the other 2 methods employed. Although several pictures taken by the camera stations show animals actually coming through the barbed wire, they seldom left hair behind. Hair was somewhat effective for detecting some of the non-target animals (e.g., eastern cottontail and woodchucks).

Overall, the agreement between methods, where there was multiple detections at a plot during the same day, was good. In every instance, both the track and photo or hair and photo were found to be from the same species. We have no way of knowing whether or not we were capturing evidence from the same individual animal or the same visit, but the lack of any instances where clear evidence showed multiple visits or more than one individual indicates this is the case. Apparently all three of these methods can provide sufficient evidence to identify the visiting animal to species (at least for mammals).

The vast majority of our target species visits were from raccoons. This could indicate that the raccoons are the most common species, or that they are more susceptible to either the detection methods or attraction by the sardine bait. Many of our raccoon observations came from a single evaluation plot (plot S106). This plot was found in close proximity to a fruiting pear tree, which likely contributed to the animals locating and visiting the evaluation plot.

We had a few evaluation plots that never recorded a visit over the entire period. Also worthy of note is the complete lack of visitation by any canids. There are several observations (by employees of RAAP) of fox (predominantly red), coyote, and domestic dog on the facility, but we never recorded any of these species visiting an evaluation plot. The same was true for felids. Although domestic cats were quite common on the RAAP and were seen frequently by observers during the course of their field work, we never documented a visit on the evaluation plots. We did however detect these species with our other sand tracking efforts. This suggests that the barbed wire arrays or the camera setup deterred these species from investigating. Another explanation might be ambivalence to the bait used, although this seems less likely.

Many of our non-target animals were likely present on the sites because of the grass clearing activities associated with plot setup. Birds, cottontails, and woodchucks especially seemed to be attracted to the new vegetation growth emerging on the plots.

ADDITIONAL SURVEY METHODS EVALUATED

Spotlight Counts

On July 17, 2003 we conducted a spotlight survey to evaluate the efficacy of this technique at the RAAP. Four observers supplied with high-powered spotlights rode in the back of a pickup truck, while the driver slowly navigated the vehicle along the same route (~6 mile) as the VDGIF deer survey. Observers used spotlights and/or binoculars to search for movement or eye shine from mammals, excluding deer. The vehicle was stopped when observers detected an animal, except deer, and observers identified the animal. We recorded the species and used a GPS to obtain geographic coordinates of the animal's location. For locations that could not be easily approached, the distance and bearing to the location was recorded, and the species' actual location was later calculated using a GIS. The survey, which took place during moderate weather conditions and good visibility, began at 21:58. The survey took 1 hr 17 minutes to complete.

Results and Discussion

We detected only 2 individuals: one raccoon and one domestic cat. Because detection rates where so low, we considered this technique sub-marginal and inefficient and did not attempt this method again. We believe this method failed because much of the RAAP is covered by grasslands and many mammals may have been obscured from view by tall grass or shrubs.

Predator Calls

On July 18, 24, and August 6, 2003, we used amplified predator calls to survey for gray and red fox. Surveys began at least 0.5 hr after sunset and continued for 1.5 to 3 hrs, depending on the number of locations surveyed. In total, 13 locations were surveyed (Figure 10). Observers used a Johnny Stewart® Bird and Animal Call system to broadcast "fox pups in distress" from select locations. Broadcasts typically lasted from 3-5 minutes followed by another 3-5 minute period of silence, and then this cycle was repeated 1 or more times. Throughout the survey, observers used binoculars and spotlights with red-filters or night vision equipment to search for animals.

Results and Discussion

No animals were detected during predator calls. Our lack of success detecting fox using this method is somewhat puzzling. This method has been used with great success in Virginia, especially to lure gray fox to the calling device (pers. comm. Mike Fies, VDGIF). Our failure to detect fox may be explained in several ways. First, perhaps no fox were present at the RAAP on the survey dates. Second, fox may have been present but did not respond. Third, fox responded and approached the surveyors but went undetected.

Given the human resources and equipment utilized during the surveys, our experience with this method and its previous success, we feel that if gray fox were present on the survey dates, they would have been detected (pers. comm. Mike Fies, VDGIF). Though some suitable habitat exists for gray fox within the study area, they are more often associated with forested areas than grasslands. Red fox, on the other hand, are often associated grassland areas, but are less likely to respond using this method. Therefore, it is possible, if not likely, that they may have been present on the survey dates but went undetected. Red fox are known to occur on the facility.

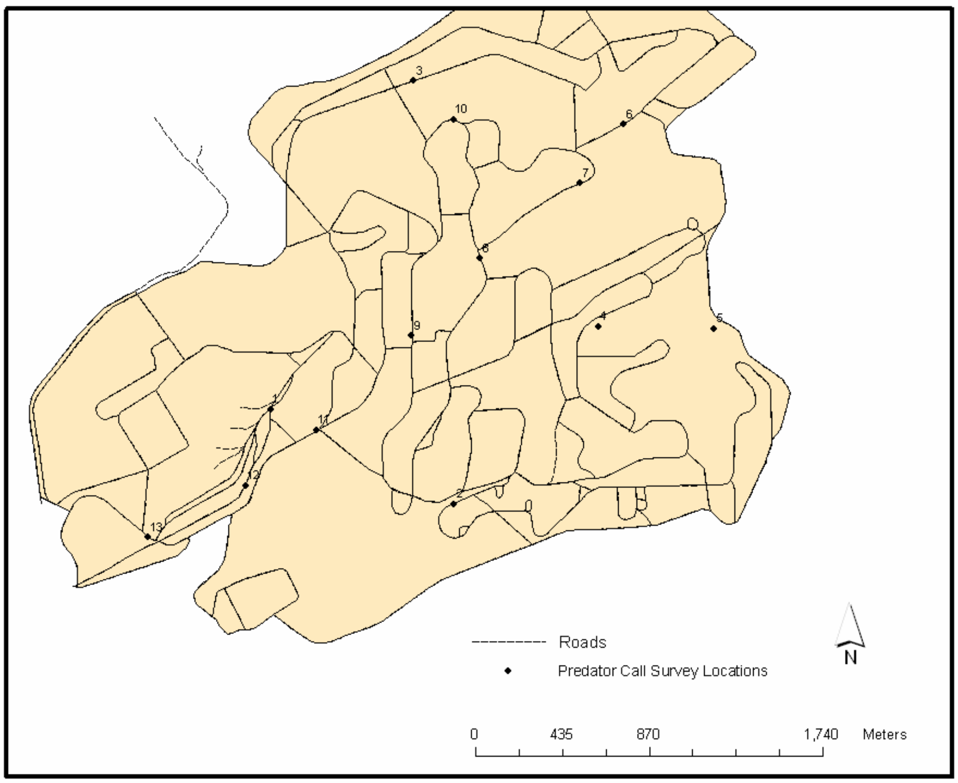

Figure 10. Distribution of predator call survey locations.

Scat Deposition Surveys

Scat deposition surveys are a reliable method to detect species presence/absence and, if sufficient data are gathered, relative abundance (Harrison *et al*. 2002). We conducted scat-deposition surveys on 3 stretches of road, 3.1, 3.2, and 3.5 km in length, respectively (Figure 11). Between 7/29 – 7/31 two observers walked each route and cleared the road of any scat present. Approximately 1 week later, on 8/5 – 8/7, and again on 8/19 – 8/21, each route was surveyed by 2 observers and all mammal scat was collected, identified, and removed from the road. We chose not to spend more effort on this method because persistent rain lessened its utility by washing away samples deposited on the road and by making samples difficult to identify.

Results and Discussion

Thirteen scat samples were collected from at least 2 species: fox (species uncertain) and striped skunk. Three additional samples could not be identified because they had been decomposed and wetted by rain. In fact, rain affected scat deposition surveys more than any other technique, because routes were checked relatively infrequently, thus almost insuring that rain occurred between data collection periods.

Because of the small sample size and spatial autocorrelation between samples, meaningful conclusions from these data are dubious. Complete results are presented in Table 7.

Table 7. Scat samples by route. Period 1 = 8/5 – 8/7, Period 2 = 8/19 – 8/21. Routes were between 3.1 and 3.5 km in length and are depicted in Figure 11. It could not be determined if the fox samples were from red or gray fox.

	Route 1	Route 2	Route 3
		Species (# samples)	
Period 1	Fox	Striped Skunk	Fox
Period 2	none	Fox (2) Striped Skunk (3)	Fox Striped Skunk Unknown (3)

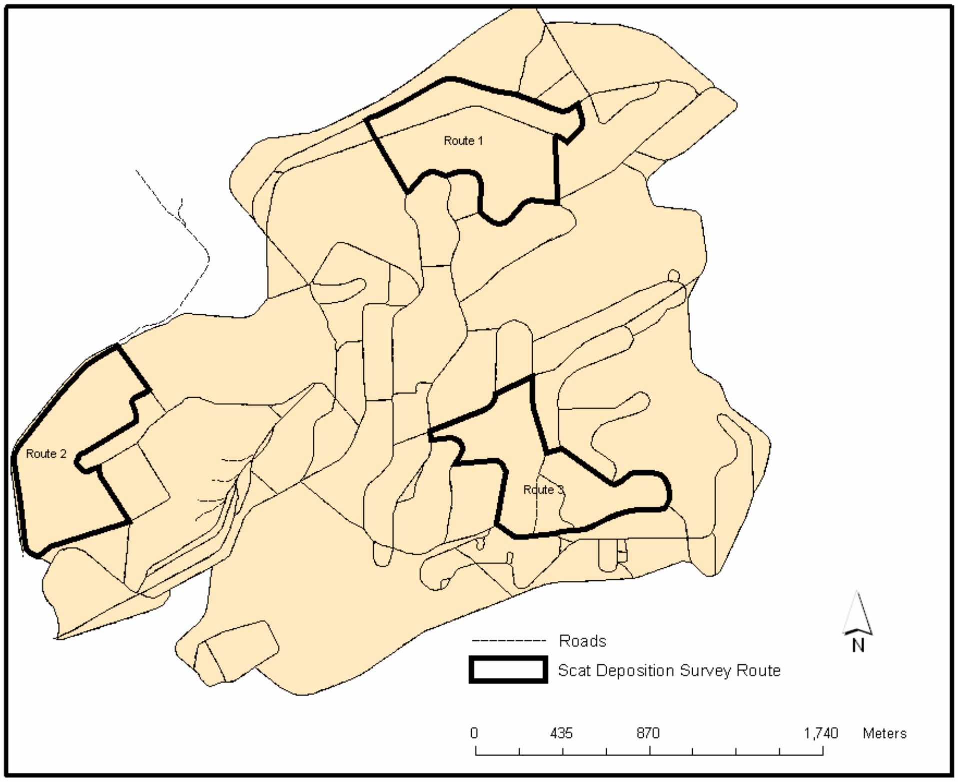

Figure 11. Scat deposition survey routes. Routes were between 3.1 and 3.5 km in length.

Incidental Species Observations

We recorded the location (using GPS) of target species, including snakes, incidentally observed during the course of field research.

Results and Discussion

In total, 22 individuals of 5 species were detected. The most common species was domestic cat (10 individuals), followed by woodchuck (4), and black rat snake (4). Other species detected were Virginia opossum (2), raccoon (1), and striped skunk (1).

SUMMARY OF CONCLUSIONS

Habitat Relationships

- We created logistic models to assess the relationship between plot use and explanatory variables for 3 target species: raccoon, Virginia opossum, and striped skunk.

- Raccoon plot use was inversely related to distance-to-fence and distance-to-deciduous forest edge, and positively related to percent cover of forbs $\geq$1 m in height.

- Virginia opossum plot use was inversely related to distance-to-fence and positively related to basal area of hardwoods $\geq$10 inches dbh and percent woody ground cover.

- No habitat or landscape variables were significantly related to striped skunk habitat use.

- Although we found significant relationships between habitat use and landscape features, these relationships were weak. Because of this, we could not confidently develop predictions for grassland nesting success as a function of predator habitat use.

- Extensive periods of rain decreased sample size for model building.

Survey Techniques

- Scent/track stations were effective and easy to operate, but rain lessened the utility of this method. On non-rain days, this method accounted for 83% of predator detections at the evaluation plots.

- The TrailMaster® active infrared trail monitoring system, used in the evaluation plots, was effective at detecting predators and relatively unaffected by weather, but developing film was expensive.

- The CamTrakker® passive infrared surveillance system, used in the scent/camera stations was not effective at detecting predators.

- Relative to other techniques, hair snares were ineffective at detecting predator species.

- Night-time spotlight surveys were ineffective at detecting predator species. Tall grass may have obscured predators.

- Predator call surveys were ineffective at detecting the presence of fox. In total, we surveyed 13 locations on 3 nights. We detected no animals with this method.

- Scat deposition surveys. We collected 13 scat samples from least 2 species: fox spp. and striped skunk. Periods of intensive rain lessened the utility of this method.

- A list of predators detected by survey type is presented in Table 8.

Table 8. Nest predator species detected by survey type.

	Camera*	Track**	Hair Snare	Spotlight	Predator Call	Scat Deposition
Raccoon	X	X	X	X		
Striped skunk	X	X				X
Virginia opossum	X	X				
Red fox		X				X***
Gray fox		X				X***
Domestic cat		X		X		
Snake spp		X				

* Evaluation plots and scent/camera stations combined
**Evaluation plots and scent/track stations combined
*** Fox spp. We were not able to identify scat to species

Index of Abundance

- Because of low sample size and spatial autocorrelation of sampling locations, we were unable to develop indices of abundance for any species. To accomplish this task, we believe that individual animals must be marked and recaptured.

LITERATURE CITED

Adorjan, A. S., and G. B. Kolenosky. 1969. A manual for the identification of hairs of selected Ontario mammals. Ontario Department of Lands and Forests. Research Report (Wildlife) No. 90.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology **11**:1-34.

Bollinger, E. K., and R. G. Peak. 1995. Depredation of artificial avian nests: a comparison of forest-field and forest-lake edges. American Midland Naturalist **134**:200-203.

Burt, W. H., and R. P. Grossenheider. 1980. A field guide to the mammals. Houghton Miffllin, Boston.

Chalfoun, A. D., F. R. Thompson, and M. J. Ratnaswamy. 2002. Nest predators and fragmentation: a review and meta-analysis. Conservation Biology **16**:306-318.

Cutler, T. L., and D. E. Swann. 1999. Using remote photography in wildlife ecology: a review. Wildlife Society Bulletin **27**:571-581.

Danielson, W. R., R. M. Degraaf, and T. K. Fuller. 1996. An inexpensive compact automatic camera system for wildlife research. Journal of Field Ornithology **67**:414-421.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science **33**:43-64.

Diefenbach, D. R., M. J. Conroy, R. J. Warren, W. E. James, L. A. Baker, and T. Hon. 1994. A Test of the Scent-Station Survey Technique for Bobcats. Journal of Wildlife Management **58**:10-17.

Fenske-Crawfored, T. J., and G. J. Niemi. 1997. Predation of artificial ground nests at two types of edges in a forest-dominated landscape. Condor **99**:14-24.

Foresman, K. R., and D. E. Pearson. 1998. Comparison of proposed survey procedures for detection of forest carnivores. Journal of Wildlife Management **62**:1217-1226.

Gehring, T. M., and R. K. Swihart. 2002. Body size, niche breadth, and ecologically scales responses to habitat fragmentation: mammalian predators in an agricultural landscape. Biological Conservation **109**:283-295.

Harrison, R. L., D. J. Barr, and J. W. Dragoo. 2002. A comparison of population survey techniques for swift foxes (Vulpes velox) in New Mexico. American Midland Naturalist **148**:320-337.

Kuehl, A. K., and R. G. Clark. 2002. Predator activity related to landscape features in northern Iowa. Journal of Wildlife Management **66**:1224-1234.

Lahti, D. C. 2001. The "edge effect on nest predation" hypothesis after twenty years. Biological Conservation **99**:365-374.

Lariviere, S. 2003. Edge effects, predator movements, and the travel-lane paradox. Wildlife Society Bulletin **31**:315-320.

Loukmas, J. J., D. T. Mayack, and M. E. Richmond. 2003. Track plate enclosures: Box designs affecting attractiveness to riparian mammals. American Midland Naturalist **149**:219-224.

Mills, D. J., B. Harris, A. W. Claridge, and S. C. Barry. 2002. Efficacy of hair-sampling techniques for the detection of medium-sized terrestrial mammals. I. A comparison between hair- funnels, hair-tubes and indirect signs. Wildlife Research **29**:379-387.

Moruzzi, T. L., T. K. Fuller, R. M. DeGraaf, R. T. Brooks, and W. J. Li. 2002. Assessing remotely triggered cameras for surveying carnivore distribution. Wildlife Society Bulletin **30**:380-386.

Myers, R. H. 1989. Classical and modern regression with applications. Brooks/Cole, Pacific Grove, California.

Nottingham, B. G., K. G. Johnson, and M. R. Pelton. 1989. Evaluation of Scent-Station Surveys to Monitor Raccoon Density. Wildlife Society Bulletin **17**:29-35.

Pasitschniak-Arts, M., R. G. Clark, and F. Messier. 1998. Duck nesting success in a fragmented prairie landscape: is edge effect important? Biological Conservation **85**:55-62.

Pasitschniak-Arts, M., and F. Messier. 1995. Predator Identification at Simulated Waterfowl Nests Using Inconspicuous Hair Catchers and Wax-Filled Eggs. Canadian Journal of Zoology-Revue Canadienne De Zoologie **73**:984-990.

Phillips, M. L., W. R. Clark, M. S. Sovada, D. J. Horn, R. R. Koford, and R. J. Greenwood. 2003. Predator selection of prairie landscape features and its relation to duck nest success. Journal of Wildlife Management **67**:104-114.

Ricklefs. 1969. An analysis of nesting mortality in birds. Smithsonian Contributions to Zoology **9**:1-48.

Sargeant, G. A., D. H. Johnson, and W. E. Berg. 1998. Interpreting carnivore scent-station surveys. Journal of Wildlife Management **62**:1235-1245.

Sargeant, G. A., D. H. Johnson, and W. E. Berg. 2003. Sampling designs for carnivore scent-station surveys. Journal of Wildlife Management **67**:289-298.

Schauster, E. R., E. M. Gese, and A. M. Kitchen. 2002. An evaluation of survey methods for monitoring swift fox abundance. Wildlife Society Bulletin **30**:464-477.

Smith, W. P., D. L. Borden, and K. M. Endres. 1994. Scent-Station Visits as an Index to Abundance of Raccoons - an Experimental Manipulation. Journal of Mammalogy **75**:637-647.

Sovada, M. A., M. C. Zicus, R. J. Greenwood, D. P. Rave, W. E. Newton, R. O. Woodward, and J. A. Beiser. 2000. Relationships of habitat patch size to predator community and survival of duck nests. Journal of Wildlife Management **64**:820-831.

Stains, H. J. 1958. Field key to guard hair of middle western furbearers. Journal of Wildlife Management **22**:95-97.

The Nature Conservancy. 1994. Standardized National Vegetation Classification System. Arlington, Virginia.

Thompson, F. R., and D. E. Burhans. 2003. Predation of songbird nests differs by predator and between field and forest habitats. Journal of Wildlife Management **67**:408-416.

Travaini, A., R. Laffitte, and M. Delibes. 1996. Determining the relative abundance of European red foxes by scent-station methodology. Wildlife Society Bulletin **24**:500-504.

VDGIF. 1999. Biological Survey of the Radford Army Ammunition Plant; including Threatened, Endangered, and Species of Concern. Virginia Department of Game and Inland Fisheries, Verona, VA.

Warrick, G. D., and C. E. Harris. 2001. Evaluation of spotlight and scent-station surveys to monitor kit fox abundance. Wildlife Society Bulletin **29**:827-832.

Wilson, G. J., and R. J. Delahay. 2001. A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. Wildlife Research **28**:151-164.

York, E. C., T. L. Moruzzi, T. K. Fuller, J. F. Organ, R. M. Sauvajot, and R. M. DeGraaf. 2001. Description and evaluation of a remote camera and triggering system to monitor carnivores. Wildlife Society Bulletin **29**:1228-1237.

APPENDICES

Appendix 1. Metadata for habitat/vegetation variables. These data collected at each sampling location and represent the habitat within 11.3 m of the plot center.

Variable Name: ba_smced
(basal area of small cedars)

Description: Basal area of cedars ≤2” dbh

Variable Name: ba_hwd_2_9_9
(basal area of hardwoods 2-10” dbh)

Description: Basal area of hardwood trees 2-10” dbh

Variable Name: ba_hwdgt10
(basal area of hardwoods ≥10” dbh)

Description: Basal area of hardwood trees ≥10” dbh

Variable Name: ba_conif2_9_9
(basal area of conifers 2-10” dbh)

Description: Basal area of coniferous trees 2-10” dbh

Variable Name: ba_conifgt10
(basal area of conifers ≥10” dbh)

Description: Basal area of coniferous trees ≥10” dbh

Variable Name: ba_snag
(basal area of snags)

Description: Basal area of snags, all size classes combined

Variable Name: can_con
(percent canopy cover, coniferous species)

Description: Percent cover coniferous species ≥2 m,

Variable Name: can_dea
(percent canopy cover, dead)

Description: Percent cover dead trees ≥2 m

Variable Name: can_hwd
(percent canopy cover, hardwood species)

Description: Percent cover hardwood species ≥2 m,

Variable Name: gc_bare
(percent ground cover, bare)

Description: Percent ground cover, bare (non-vegetated)

Variable Name: gc_forb
(percent ground cover, forbs)

Description: Percent ground cover, forbs

Variable Name: gc_gram
(percent ground cover, graminoids)

Description: Percent ground cover, graminoids

Variable Name: gc_litter
(percent ground cover, litter)

Description: Percent ground cover, litter, such as pine needles, other leaves

Variable Name: gc_wdebris
(percent ground cover, woody debris)

Description: Percent ground cover, woody debris, such as downed branches, etc

Variable Name: gc_woody
(percent ground cover, woody)

Description: Percent ground cover, woody/shrubs

Variable Name: m_conif
(percent midstory cover, coniferous species)

Description: Percent cover coniferous species 1-2 m

Variable Name: m_dead
(percent midstory cover, dead)

Description: Percent cover dead trees/shrubs 1-2 m,

Variable Name: m_gram
(percent midstory cover, gramimiods)

Description: Percent cover gramimiods (grasses) 1-2 m

Variable Name: m_forb
(percent midstory cover, forbs)

Description: Percent cover forbs 1-2 m

Variable Name: m_hwd
(percent midstory cover, hardwoods)

Appendix 2. Metadata for landscape/spatial variables. These data were created using a GIS.

Variable Name: HI
(Heterogeneity Index)

Description: HI = ((Total Perimeter – Buffer Perimeter)/2)/ Total Area

Total Area (m^2) = area of 100m buffers around study plots
(*n*=20 of 113 truncated by exclusion of areas outside fence)
Total Perimeter (m) = length of polygon boundaries contained within buffers (including outer perimeter)
Buffer Perimeter (m) = length of outer perimeter of buffers

Variable Name: D2_fence
(distance to fence)

Description: minimum distance (m) of study plot to perimeter fence line around study area as assigned by geo-processing spatial join

Variable Name: D2_roads
(distance to roads)

Description: minimum distance (m) of study plot to roads as assigned by geo-processing spatial join

Variable Name: D2for_d
(distance to forest-deciduous)

Description: minimum distance (m) of study plot to area classified as deciduous forest from raster output (grid cell size 1m) of Raap_forest_deciduous polygons (coverclass 1.0)

Variable Name: D2for_c
(distance to forest-conifer)

Description: minimum distance (m) of study plot to area classified as coniferous forest from raster output (grid cell size 1m) of Raap_forest_conifer polygons (coverclass 1.1)

Variable Name: D2for_m
(distance to forest-mixed)

Description: minimum distance (m) of study plot to area classified as mixed forest from raster output (grid cell size 1m) of Raap_forest_mixed polygons (coverclass 1.2)

Variable Name: D2wlnd_d
(distance to woodland-deciduous)

Description: minimum distance (m) of study plot to area classified as deciduous woodland from raster output (grid cell size 1m) of Raap_woodland_deciduous polygons (coverclass 2.0)

Variable Name: D2wlnd_c
(distance to woodland-conifer)

Description: minimum distance (m) of study plot to area classified as coniferous woodland from raster output (grid cell size 1m) of Raap_woodland_conifer polygons (coverclass 2.1)

Variable Name: D2wlnd_m
(distance to woodland-mixed)

Description: minimum distance (m) of study plot to area classified as mixed woodland from raster output (grid cell size 1m) of Raap_woodland_mixed polygons (coverclass 2.2)

Variable Name: D2grslnd
(distance to grassland)

Description: minimum distance (m) of study plot to area classified as grassland from raster output (grid cell size 1m) of Raap_grassland polygons (coverclass 3.0)

Variable Name: D2edge
(distance to edge)

Description: minimum distance (m) >0 of study plot to area classified as a different coverclass than the one in which the study plot is located

Variable Name: pcfor_d
(percent forest-deciduous)

Description: percent composition by area of 100m buffers around study plots classified as deciduous forest (coverclass 1.0)

Variable Name: pcfor_c
(percent forest-conifer)

Description: percent composition by area of 100m buffers around study plots classified as coniferous forest (coverclass 1.1)

Variable Name: pcfor_m
(percent forest-mixed)

Description: percent composition by area of 100m buffers around study plots classified as mixed forest (coverclass 1.2)

Variable Name: pcwlnd_d
(percent woodland-deciduous)

Description: percent composition by area of 100m buffers around study plots classified as deciduous woodland (coverclass 2.0)

Variable Name: pcwlnd_c
(percent woodland-conifer)

Description: percent composition by area of 100m buffers around study plots classified as coniferous woodland (coverclass 2.1)

Variable Name: pcwlnd_m
(percent woodland-mixed)

Description: percent composition by area of 100m buffers around study plots classified as mixed woodland (coverclass 2.2)

Variable Name: pcwldal
(percent woodland-all)

Description: percent composition by area of 100m buffers around study plots classified as deciduous woodland, coniferous woodland, and mixed woodland combined (coverclass 2.0 + 2.1 + 2.2)

Variable Name: pcgrslnd
(percent grassland)

Description: percent composition by area of 100m buffers around study plots classified as grassland (coverclass 3.0)

Appendix 3. Example SAS Code used to assess the relationships between plot use and explanatory variables.

PROC LOGISTIC was used in the first stage of analysis to select the best model.

```
proc logistic data=X2 descending ;
        class dominant_species bait ;
        model detected_= Bait Dominant_Species Date3 Xcoord Ycoord
        HI D2_fence D2_roads D2for_d D2for_c D2for_m D2wlnd_d D2wlnd_c D2wlnd_m
        D2wlndal D2grslnd D2edge pcfor_d        pcfor_c pcfor_m pcwlnd_d pcwlnd_c pcwlnd_m
        pcgrslnd pcwlndal ba_smced ba_hwd_2_9_9 ba_hwdgt10          ba_conif2_9_9
        ba_conifgt10 ba_snag can_con can_dea can_hwd gc_bare gc_forb gc_gram gc_litter
        gc_wdebris gc_woody m_conif m_dead m_gram_forb m_hwd
        / selection =stepwise slentry=0.1 slstay=0.05 ;
run;
```

PROC GENMOD was used in stage two to test for temporal correlations among observations.

```
proc genmod data=X2  descending ;
        class plot;
        model detected_ =  Var1 Var2 Var3
       /dist=bin link=logit;
        repeated subject=plot/ type=UN covb corrw;
run;
```