Assessing the Effectiveness and Reliability of the Roadside Animal Detection System on US Highway 41 near the Turner River in Collier County

Final Report

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Principal Investigators -

Daniel J. Smith, Ph.D., A.I.C.P., Research Associate
Principal Investigator

Reed F. Noss, Ph.D., Davis-Shine Professor of Conservation Biology
Co-principal Investigator

Department of Biology
University of Central Florida
Orlando, FL 32816

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Report Authors

Daniel J. Smith, Molly K. Grace, Ashley Miller, Myra J.W. Noss and Reed F. Noss

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Executive Summary

In 2012, the Florida Department of Transportation (FDOT) installed a roadside animal detection system (RADS) on a 1.3 mi section of US 41 near the Turner River in Big Cypress National Preserve (BCNP). This location, approximately 40 mi east of Naples was identified by wildlife agencies as a critical hotspot for vehicle-related deaths of the Federally endangered Florida panther. The intent of RADS was to reduce wildlife-vehicle collisions and improve motorist safety. Target species include Florida panther, Florida black bear, bobcat, white-tail deer and American alligator. The RADS functions by projecting a continuous infra-red beam between multiple integrated transmitters and receivers; when an animal crosses the path between a transmitter and receiver the beam is broken which triggers flashing lights on warning signs that alert drivers of wildlife present in the roadway.

The goal of this study was to assess the reliability of the RADS in correctly detecting target wildlife species that enter the roadway and the effectiveness of the warning signage in reducing speed and increasing driver alertness. The study was conducted from January 2013 to May 2015. We conducted roadkill surveys and set up track and camera trap stations to document presence of animals that are potentially affected by the RADS system. Two panthers were killed in vehicle collisions in the RADS zone in 2012. Other road-killed target species included American alligator (14), white-tail deer (1) and river otter (1). Tracks of target species observed included Florida panther (61), bobcat (131), Florida black bear (64), white-tail deer (82) and American alligator (2). On camera traps we captured Florida panther (91), bobcat (239), Florida black bear (50), white-tail deer (927) and American alligator (6). Target species movement across US 41 was documented at three primary locations, Trail Lakes landbridge, Turner River canoe launch and Turner River Road. Recommendations are provided to improve detection capabilities at these key locations.

We deployed trail cameras in 5 strategically located RADS sensor sections and compared date/time stamps of photographic data to sensor logs to tabulate successful detections, false negatives and false positives. Overall, the RADS performed from poor to fair in detecting target species; we recorded average success rates between 10.7% and 66%. We also found that on average, between 34% and 89.3% of target animals were not detected, resulting in false negatives. Over 90% of all RADS activations were classified as false positives. The resulting effect is that the large number of false positives could be desensitizing drivers to the RADS. If the RADS is constantly flashing and animals are not present, they may begin ignoring the warning system. Several possibilities exist to explain the high level of false positives including physical obstructions, adverse environmental effects, and mechanical/electronic malfunction. The problem is likely multi-causal in nature. Troubleshooting the causes and rectifying these is critical to the systems success and evaluation.

Use of a control site to test the RADS did not provide measurably better detection success or reductions in false negatives, however it did result in reducing the number of false positives by nearly 50% below that of the US 41 system. Although it was easier to control for some constraints on US 41 such as vegetation growth or vehicles pulling off the road and triggering the sensor, we still encountered system malfunctions that negatively affected results.

To assess driver response to RADS, we measured the speed of individual cars on US 41 when the RADS was active (flashing) and inactive (not flashing). In the tourist season, the activation of the RADS caused a significant reduction in vehicle speed (2.37 mph). There was a significant interaction between season and time of day. During the tourist season, drivers drove faster (3.44 mph) at twilight than at night. The

same effect was observed in the off-season, though the difference was not as large (1.96 mph). The overwhelming factor influencing speed was time of day. Despite the fact that drivers in the tourist season generally drove faster than those in the off-season, tourist-season drivers responded to the RADS by driving more slowly, while off-season drivers did not. We suggest that this result is from acclimation by local drivers to the RADS.

We also tested the effectiveness of the RADS in a controlled setting using a driving simulator. The RADS driver simulation produced significant positive results: 1) participants in RADS treatments reduced speed, 2) braked earlier in response to an animal in the road, and 3) were involved in animal-vehicle collisions less often. In addition, picture-based RADS signs were more effective than word-based RADS signs at reducing driver speed at twilight, and the same was true for differences in reaction time (braking distance) at night. These results lend empirical support to survey results that drivers rate picture-based signs higher for increasing alertness. Although less crashes occurred in picture-based treatment than in word-based treatment, this difference was not significant. However, this could be the result of a relatively low sample of crashes in our study; with more participants, we suspect that these trends would become significant.

Adequate notification of animal presence, or lack thereof, by clearly visible signs was another issue identified in the study. First, clutter, sensory overload and obstructed view from too many signs in very close proximity appears to be a significant problem at many of the locations where RADS warning signs were placed. In addition, we identified two gaps in the sensor zone where drivers are not warned by the current number and placement of RADS warning signs.

Results of the citizen survey demonstrated that the public is generally unfamiliar with the RADS system, its purpose and how it functions. For RADS to be effective, public education is essential as the system relies heavily on driver response. Efforts to increase public understanding and driver awareness are needed.

Roadside animal detection systems are a promising technology in reducing the frequency of animal-vehicle collisions, but empirical testing on US 41 has demonstrated chronic system malfunctions. Findings of the simulator experiment suggest that RADS can indeed produce the intended results on reducing crash probability, driver speed, and latency to brake. Several recommendations are provided herein to improve system reliability and effectiveness.

Introduction

District One of the Florida Department of Transportation (FDOT) installed a roadside animal detection system (RADS) in 2012 on US 41 near Turner River in Collier County, a location approximately 40 mi east of Naples. The project area includes a 1.3 mi. long road segment within Big Cypress National Preserve (BCNP) (fig. 1). This location in the BCNP on US 41 was identified by several federal and state wildlife agencies as a critical hotspot for vehicle-related deaths of the federally endangered Florida panther. Eight deaths (7 vehicle collisions, 1 unknown) of panthers were recorded from 1984 to 2012. Seven of these occurred between 2004 and 2012 and 62.5% were breeding-age females. The RADS was intended to reduce wildlife impacts and improve motorist safety. The target species were Florida panther, Florida black bear, bobcat, white-tail deer and American alligator, although other large wildlife would also benefit from the animal detection system.

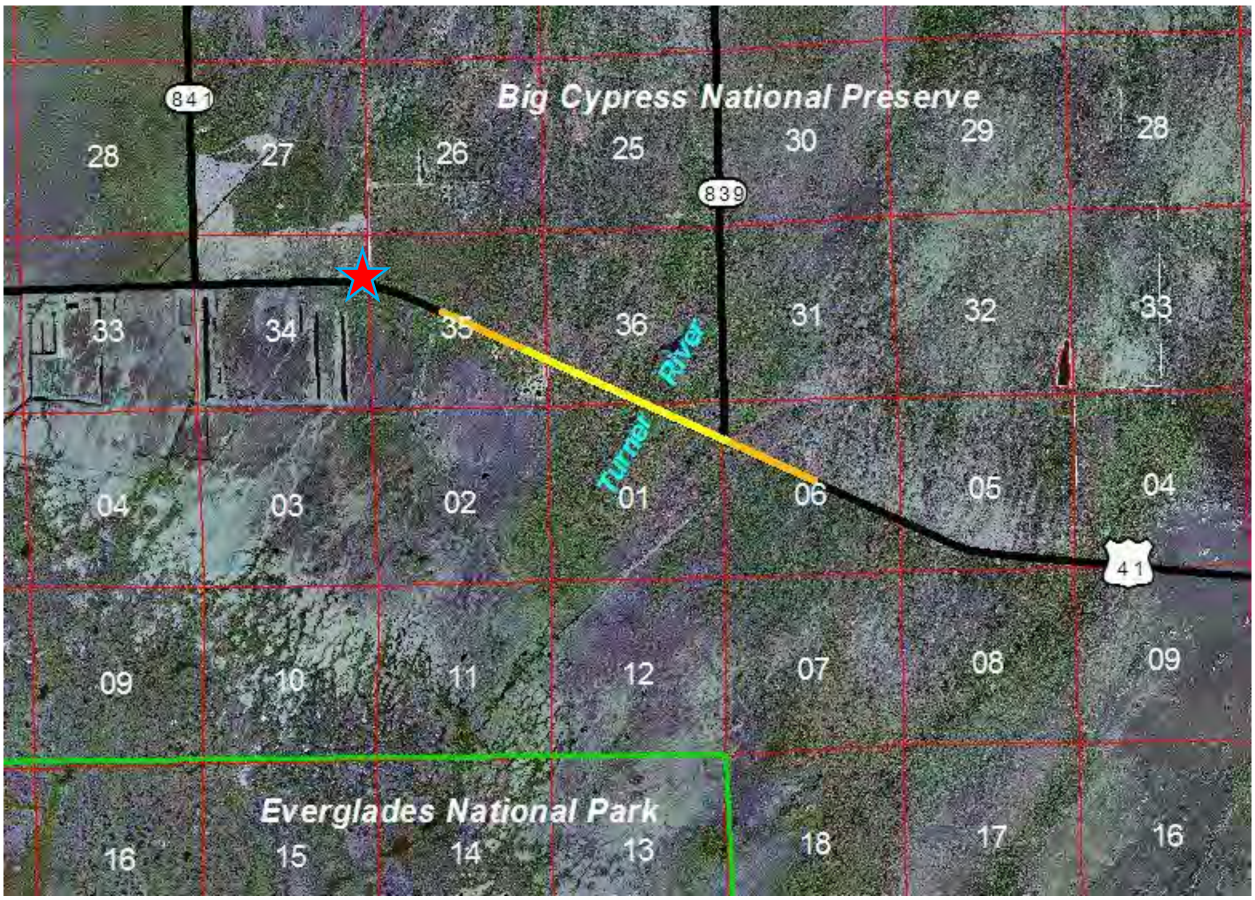

Figure 1. US Highway 41 Project Area near Turner River in Collier County. Notes: The RADS segment length in yellow (approx. 1.3 mi); driver warning sign lead distance in orange (approx. 0.5 mi). This location is approximately 40 mi east of Naples; The Community of Ochopee is denoted by the red and blue star.

Animal-vehicle collisions affect human safety, property, and wildlife. Most collisions affect small mammals and herpetofauna, though Huijser and McGowan (2003) cited that 90 percent of ***reported*** collisions involve deer. Collisions with larger mammals frequently lead to severe damage to vehicles and injury to their occupants, result in increased mortality in animal populations, and reductions in connectivity of adjacent habitats. Thus, roads represent one of the greatest threats to wildlife worldwide (Trombulak and Frissel 2000, Forman et al. 2003, van der Ree et al. 2015) and annually cause an average of 200 human fatalities, 26,000 human injuries, and over one billion dollars in property damage (Huijser and McGowan 2003, Huijser et al. 2008).

Mitigation measures have been utilized with varying degrees of success and cost, and new technologies are being developed to address the needs of growing road networks and older networks experiencing higher traffic volumes. Mitigation measures vary widely though new technology such as animal detection and warning systems have the potential to address key issues that occur with other road mitigation measures. For example, fencing reduces mortality, but reduces the permeability of roads, creating issues with population isolation and diminished access to critical resources (Smith 2003). Standard road signage can quickly become ineffective as drivers habituate to such signage and fail to make adequate reductions in speed (Huijser et al. 2008). Wildlife crossing structures are effective in conjunction with adequate roadside fencing, though these structures are costly and are usually only installed during road construction or road modification projects (Huijser et al. 2008, van der Ree et al. 2015). Animal detection systems may address these and other issues by increasing road permeability while reducing collisions at a lower installation cost.

Site conditions are an important factor when selecting a mitigation measure, and animal roadside warning and detection systems may not be effective at all sites. However, continued testing and calibration of these systems may lead to widespread deployment in sites where large animals attempt road crossings and where frequent collisions occur.

Goal and Objectives

The goal of this study was to determine the reliability of the roadside animal detection system in correctly detecting target wildlife species that enter the roadway and the effectiveness of the warning signage in obtaining a positive response (slower speeds, increased alertness) from drivers.

This study included the following objectives:

1. **Determine the reliability of the RADS in correctly detecting target wildlife species.**

    a. Collect and compare onsite field data from the RADS and infra-red camera and track stations.
    b. Obtain and analyze any pre-installation data such as species inventories and results from previous road-kill, wildlife movement and population studies and habitat assessments.
    c. Collect and analyze post-installation road-kill data for the project area.
    d. Conduct a RADS reliability experiment in a controlled location using video and/or still camera monitors on target wildlife species.

2. **Evaluate the effectiveness of the warning signage in reducing vehicle speed and increasing driver awareness.**

    a. Conduct on-site vehicle speed study.
    b. Prepare and distribute driver questionnaire to evaluate public perception/reaction to the function, effectiveness and importance of the RADS.
    c. Evaluate driver response time (speed reduction) to the RADS warning signage and alertness to presence/absence of target wildlife species using a driving simulator.

Approach to Evaluating System Performance

Performance of the roadside animal detection system was evaluated by examining the ability of the sensor array to accurately detect the target wildlife species and the effect that the warning system had on driver behavior. A broad approach that employed a few key methods was used to determine the reliability and effectiveness of the roadside animal detection system in improving vehicle safety and reducing large wildlife-vehicle collisions.

First, on-site and control site evaluations of system reliability were performed. On-site studies included monitoring wildlife movement within the range of the US 41 RADS sensor array. We used infra-red cameras and track beds to tabulate the number of target species crossing in front of sensors, and compared these counts to the number recorded by the sensor array. We identified a suitable control site located in Seminole State Forest/Rock Springs Run Preserve State Park in central Florida adjacent to a high traffic road (SR 46) and an existing wildlife crossing structure where the volume of animal usage was high enough to collect sufficient data. This location excluded many of the environmental variables and human access issues that confounded evaluation of the RADS system on US 41. Another benefit of the control location was the ability to obtain higher sample sizes to perform statistics on the sensor's performance in reliably detecting target species (i.e., percentage of false negatives and false positives).

Second, we evaluated effectiveness of the warning system and acceptance by the driving public by conducting a vehicle speed study and creating and distributing a citizen questionnaire. To evaluate driver response to the animal warning signals and signage, we monitored vehicle speed during controlled experiments. This included manual manipulation of the warning signal lights and evaluating change of vehicle speed as a result. We also created a written questionnaire that was used to poll the driving public within the US 41 study area. It was also made available online. The purpose of the questionnaire was to poll drivers regarding: 1) general experiences with encounters of wildlife on roads; 2) knowledge of the function, applicability, and importance of the RADS, and 3) knowledge of this RADS installation including reaction and/or response to positive/negative system function.

Third, a driving simulator was used to evaluate the effect of the RADS on driver alertness. We created a simulation program that emulated a roadway similar to the US 41 project area including the RADS system. Test subjects were exposed to random presence of target wildlife species in scenarios with and without advanced warning signals and signage. We investigated two parameters related to effectiveness of RADS warning signs/signals, day/night and word-based vs. picture-based warning signs. Test subjects were graded according to speed reduction, braking response time and alertness.

Study Area

The study area includes a 2.5 mile section of US Highway 41 located entirely within the Big Cypress National Preserve (BCNP), approximately 40 mi east of Naples (fig. 1 and fig. 2). Land cover consists of a mosaic of cypress swamp, hardwood swamp, mixed wetland forest, freshwater marsh, salt marsh, mangrove swamp, pinelands, hardwood hammock, cypress/pine/cabbage palm, and sparse rural development (FFWCC land cover 2015). A prominent feature within the project area is the Turner River that includes a recreational area with a canoe/kayak launch. At the west end of the project area is the Trail Lakes Campground and at the east end is H.P. Williams Park with picnic tables and an observation boardwalk. The project area is bordered to the west by the small community of Ochopee, FL with a population of 232 (US Census, 2010).

west end of project area facing east

east end of project area facing west

Turner River, facing south of US 41 bridge

eastside of Turner River facing west

Figure 2. Photographs of US Highway 41 Right-of-Way in the Project Area in Big Cypress National Preserve.

The roadside animal detection system (RADS) is located on a 1.3 mi section of the road beginning just east of Turner River Road (CR 839) and extending westward (fig. 3). Message signs that inform motorists about the RADS are located approximately 0.5 mi in each traffic direction before and after entering the sensor zone (figs. 3, 4). Traffic volume for the project area was 2,600 vehicles per day, on average in 2010. Posted speed limits are 60 mph in daylight, 45 mph at night. A permanently inundated canal is immediately adjacent and parallel to the roadway on the northside. The road configuration (narrow right-of-way and clear zone and dense roadside vegetation), rural context and low traffic volume often lead to increased and unsafe vehicle speeds and reduced driver visibility, and in turn reduced reaction times to road hazards. These road and traffic characteristics form a high-risk zone for wildlife movement within the BCNP. The road is traversed by the federally endangered Florida panther, Florida black bear, white-tail deer, American alligator, as well as many other wildlife species. Consequently, these animals are subject to vehicle collisions. For example, eight Florida panthers and one Florida black bear have been documented in vehicle collisions from 1996 to 2014 (FFWCC 2015). Three additional Florida black bears were killed by vehicles within 2 mi of the project area.

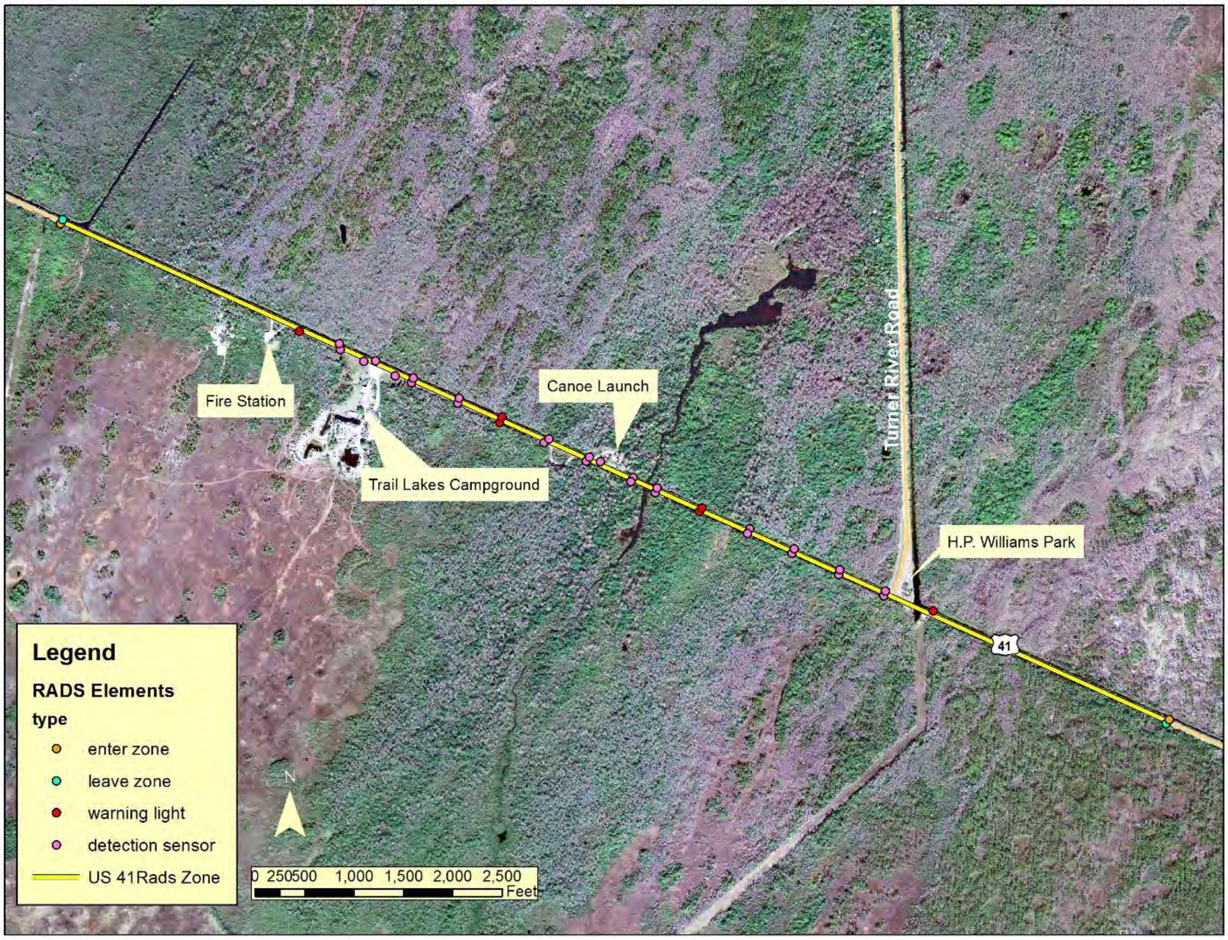

Figure 3. Site Map of the Study Area Displaying Locations of various RADS Signs and Sensors.

Summary of RADS Equipment and Function

The hardware configuration of the RADS consists of two daisy-chained arrays of"break-the-beam" type sensors situated off each shoulder on both sides of the highway running parallel to the pavement. The spacing between sensors is approximately 500 ft (fig. 3). These detection devices are placed 18 in above the ground in keeping with a height that will capture movement of the target species (fig. 5). The "break the beam" sensor device consists of an infra-red transmitter and receiver. It functions by projecting a continuous infra-red beam from the transmitter to the receiver; when an animal crosses the path between the transmitter and receiver the beam is broken which triggers flashing lights on warning signs that alert drivers of wildlife present in the roadway. Spacing between the wildlife warning signs (equipped with lighted warning beacons; fig. 6) is specified at 2,000 ft (fig. 3). The detectors and warning beacons comprise an integrated system connected by wireless communications technology that can be monitored and controlled by a central computer. All field devices within the system along US Highway 41 are solar powered. The system includes a manual control override device on-site that can be used for maintenance and research purposes. Driveways within the sensor zone include a magnetic loop that informs the system when vehicles "break" the beam; in these instances the warning lights are not triggered. Animals or people crossing over the driveways between sensor poles will trigger the warning beacon lights.

Figure 4. Standard Diamond-shaped Warning Signs Notifying Drivers that They Are Entering/Leaving the RADS Sensor Zone. Note: these signs are posted ½ mi prior to entering and after leaving the RADS sensor zone.

Figure 5. RADS Sensor Device. Note: RADS is a solar powered, multi-sensor integrated system with transmitters and receivers spaced about 500 ft apart. An infra-red beam is projected between the devices.

Figure 6. Standard Diamond-shaped Warning Signs with Lighted LED Beacons around the Perimeter of the Sign. Note: When triggered the flashing LED lights indicate that animals are present in the road right-of-way.

Research Focus Areas

A. Animal Presence: Road-kill, Tracks and Images

We conducted roadkill surveys, and set up track and camera stations to document presence of animals that are impacted by the RADS system. In addition, we also reviewed other data sources and previous studies from the study area. Target species included Florida panther, Florida black bear, white-tail deer, bobcat, and American alligator. We also recorded all other species at least 18 in height that could trigger the RADS sensors (see previous section – Summary of RADS Equipment and Function).

Methods

Other Data Sources – We reviewed previous data collected on target species movements and/or location records. This information was used to facilitate and verify results from newly conducted field work.

Roadkill Surveys – US 41 within the project area was surveyed for road-kills near dawn hours 2-3 times weekly for approximately 27 months beginning in January of 2013. Field technicians walked or drove (10 mph or less) the roadside and recorded locations of road-kill occurrences, documenting species type, age class and sex of each individual. Target species road-kills encountered while performing other activities at the project site were also recorded.

Track Monitoring – Only a portion of the project length was suitable for track beds because of unsuitable substrate (limerock base) and right-of-way width and safety concerns. We constructed track beds at several stations where wildlife crossing activity was observed (fig. 7). These consisted of 3-4 ft wide strips of sand 4-6 in deep created on the roadside parallel to the road (fig. 8). Builders grade sand was required as a supplement because the existing substrate was unsuitable. Each track station was checked twice weekly for tracks. Monitoring occurred continuously for approximately 27 months beginning in February of 2013. Species type, date, track location and special habitat features were recorded.

Infra-red Trail Camera Monitoring – Given that the study area length is 1.3 miles and night-range of an infra-red camera is approximately 30 ft, it was not cost-feasible to purchase and install cameras to monitor the entire length of the project. As a result, we selected sensor sections where wildlife crossing frequency was greatest. These included three primary locations: Trail Lakes landbridge, Turner River canoe launch and Turner River Road (fig. 9). We used cameras to cover 5 separate sensor sections, two on the southside of the road and three on the northside (one of these consisted of the Turner River canoe launch entrance). We set up camera arrays at the Turner River Road location despite the absence of RADS sensor coverage because of previous wildlife crossing observations of US 41. Camera monitoring occurred from Apr 2013 to Apr 2015. Cameras were checked every two weeks to download images, maintain batteries and update date/time. All images were date and time stamped to correlate with animal counts recorded by RADS animal detection sensors. On the southside of the road, trail camera arrays consisted of a row of trail cameras approximately 35 ft apart spanning the length of the sensor section (fig. 10). On the northside, camera arrays only spanned constricted crossing points, such as a road, driveway or landbridge over the canal. An example of the latter, at Turner River canoe launch, is shown in fig. 11.

Results and Discussion

Other Data Sources – Location and date of Florida panther mortalities was obtained from FFWCC (fig. 12). Two mortalities occurred within the wildlife detection sensor zone following installation of RADS in 2012. Another panther was killed in a collision in 2012 approximately 1,000 ft west of the eastbound RADS “entering the wildlife detection zone” sign.

A pre-installation study was conducted for FDOT by WilsonMiller Stantec from Mar - Jun 2011 that included recording wildlife observations, both road-kills as well as occurences obtained by using trail cameras or live observation. Species documented included the same taxonomic assemblages that were observed in the current study. In general, the locations and repeated use of the land bridges by Florida panther and other target species correspond to our findings. Refer to the report for more information on the data collected in this effort (WilsonMiller Stantec 2011).

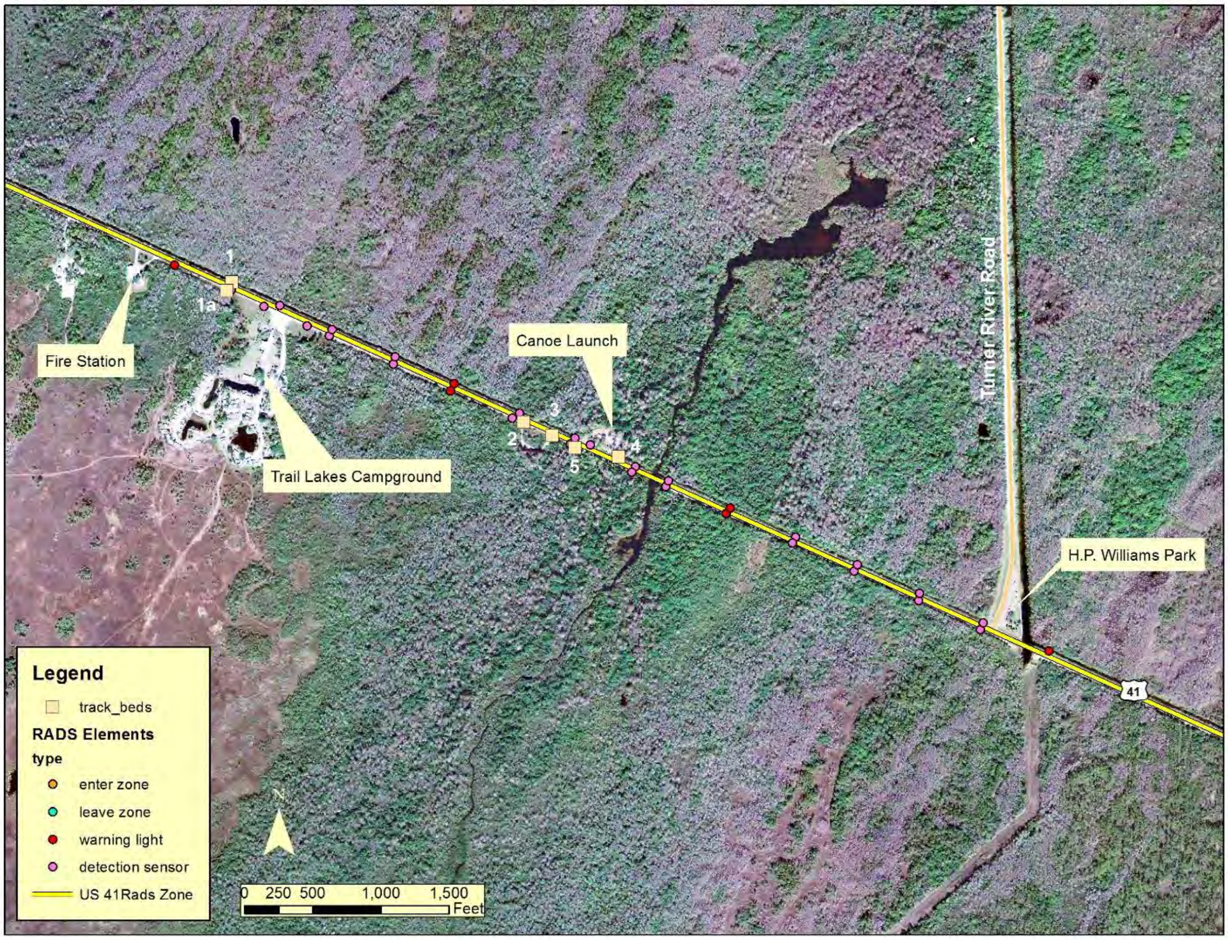

Figure 7. Location of Constructed Sand Track Stations for Detecting Footprints of Target Species. Note: These locations correspond to land bridges over the northside canal and where wildlife had been frequently observed crossing the road.

Road-kill Surveys –We recorded road-kill from Jan 2013 to Apr 2015. Our primary objective was to identify any carcasses of animals large enough to trip RADS sensors. Smaller road-killed animals, however, are prey items that often attract the larger target species. Therefore, we recorded all road-kill from Jan 2013 to Feb 2015 to offer an indication of the relative amounts of other smaller species that were victims of vehicle collisions and where the majority of these occurred (Appendix A). Although we cannot say with absolute certainty that we recorded all large animals that were victims of vehicle collisions, we believe we counted most because these animals were large enough that removal by scavengers was less likely. In addition, field technicians were mostly present at the study site five days per week, and they were instructed to record newly occuring large road-kills even on days when road-kill surveys were not being conducted.

Figure 8. Track Bed Station #1 Spans the Landbridge over the Canal on the Northside of US 41 near Trail Lakes Campground. Note: photo shows the smoothing of the sand surface to make it easier to read animal prints.

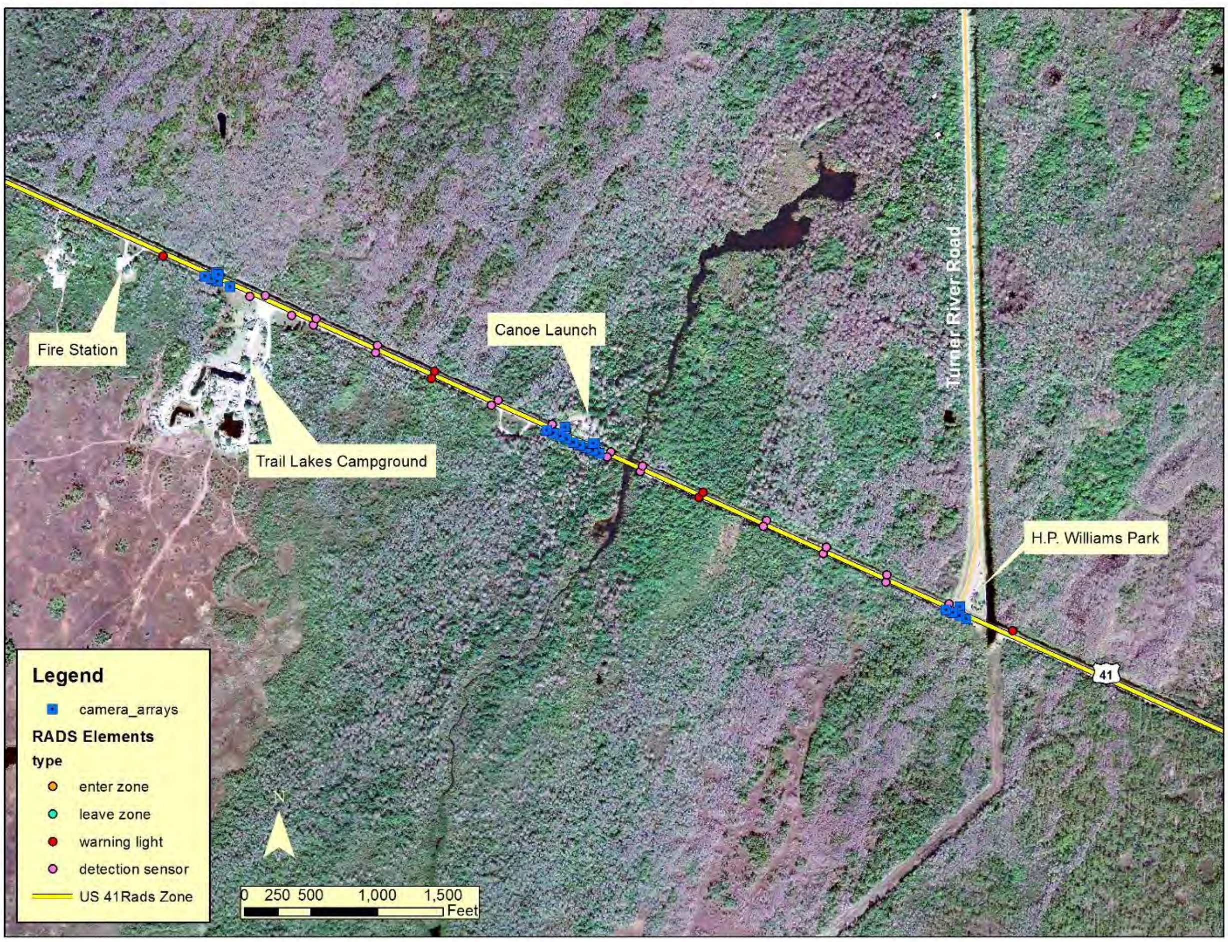

Figure 9. Location of Camera Trap Arrays for Detecting Movements Across US 41 by the Target Species. Notes: These locations correspond to "land bridges" (terrestrial connections) over the northside canal and where wildlife had been frequently observed crossing the road; these locations are referred to as Trail Lakes landbridge, Turner River canoe launch and Turner River Road.

Figure 10. Partial View of the Camera Trap Array on Southside of US 41 at the Turner River Canoe Launch. Note: the camera array consisted of a series of cameras mounted on posts approx. 18 in above ground level and spaced approx. 35 ft apart (denoted by red arrows) that span the length of the sensor section.

Table 1 displays the number of recorded road-killed animals large enough to trip RADS sensors. Alligators and long-legged birds were encountered most often. The number of large animals recorded was too low to detect any seasonal variation in occurrence. The study area was divided into 25 m (82 ft) segments to record and display spatial patterns of road-kills. Focal species road-kills observed are displayed in fig. 13. One location of note included 7 alligators all found dead on the road about 1,000 ft east of Turner River.

Track Monitoring – Track bed stations are shown in fig. 7. Track bed #s 1 and 1a are located at a feature known as the Trail Lakes landbridge, a terrestrial connection over the northside canal. Track bed #1 is on the northside of the road and track bed #1a is on the southside of the road. Combined, these track beds demonstrated the highest presence by Florida panther (n=44), Florida black bear (n=34), bobcat (n=68) and white-tail deer (n=53) (Table 2). Uniquely, animals crossing over the canal at this site must cross through track bed #1 on the northside (fig. 8), however they do not necessarily cross through track bed #1a on the southside of the road. This explains the disparity in the volume of tracks in each of these track beds (Table 2). Animals come and go at many angles from the road on the southside as they are not limited by the canal for movement perpendicular to the road. We were able to capture the variable direction of movement on the southside by using trail cameras. A high presence of humans was also noted at track bed #1 (n=202). Meso-mammals (raccoon and Virginia opossum) were common (track bed #1, n=184) and on occasion may trip sensors given their posture and precision of the infra-red beams.

Figure 11. Camera Trap Array and Track Bed Station at the Turner River Canoe Launch. Notes: two camera traps were attached to the guardrail as shown on the left side of the upper photograph (circled); track bed #4 (as shown in the center of the upper photograph), adjacent to a headwall next to a shallow overflow drainage swale (lower photograph), spanned the pathway to this crossing and coincided with the canoe launch ramp; high public use occurs at this site.

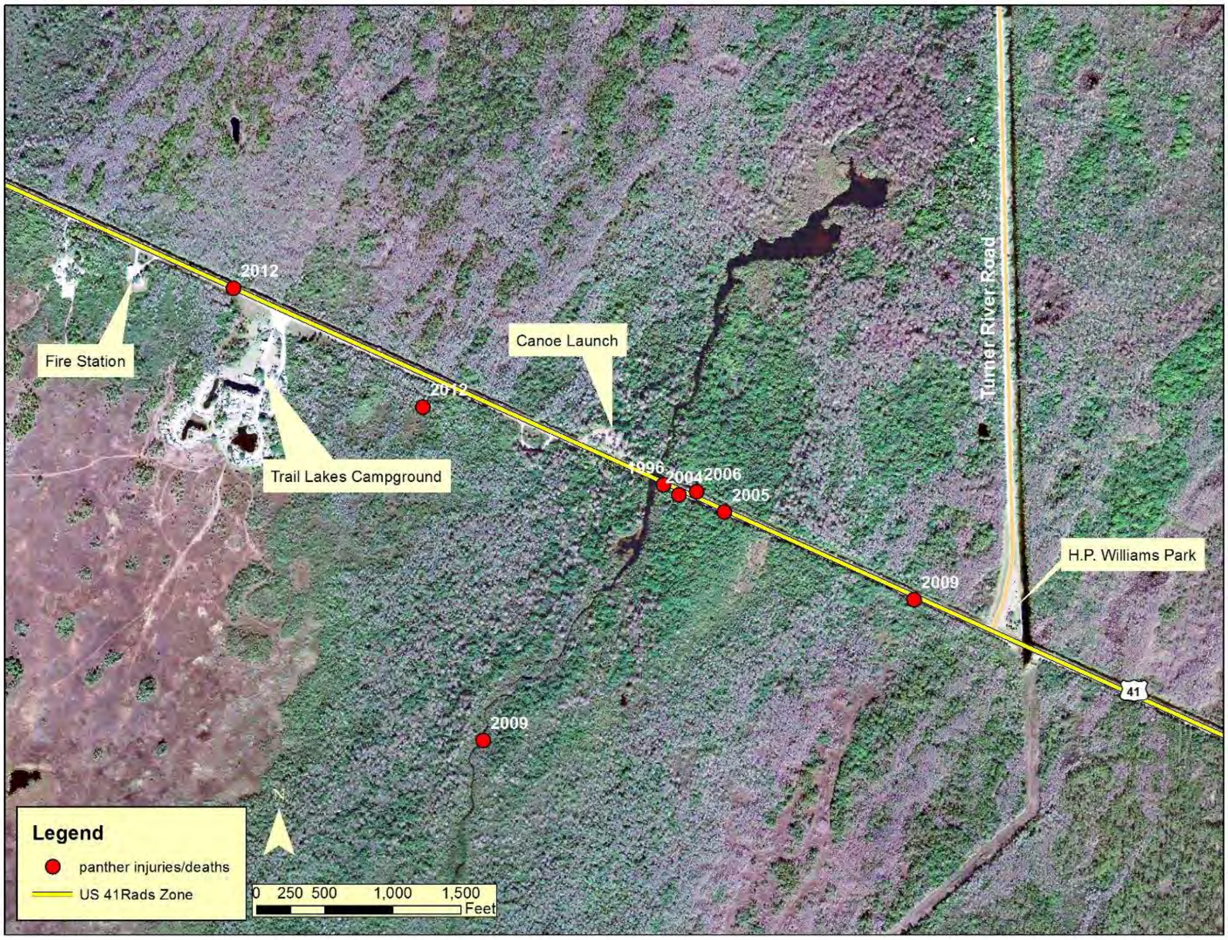

Figure 12. Location of Florida Panther Mortalities and Injuries from Vehicle Collisions. Notes: Cause of mortality for the location approx. 2,000 ft south of US 41 was listed as unknown; Data source: FFWCC 2014.

Table 1. RADS Road-kills Recorded from January 2013 to April 2015.

Species	#	%
American alligator	14	66.67
Florida panther	0	0.0%
Bobcat	0	0.0%
Florida black bear	0	0.0%
Canidae	0	0.0%
white-tail deer	1	4.76%
river otter	1	4.76%
long-legged birds	5	23.81%
total	21	

Notes: Detailed species lists and additional analysis are provided in Appendix A.

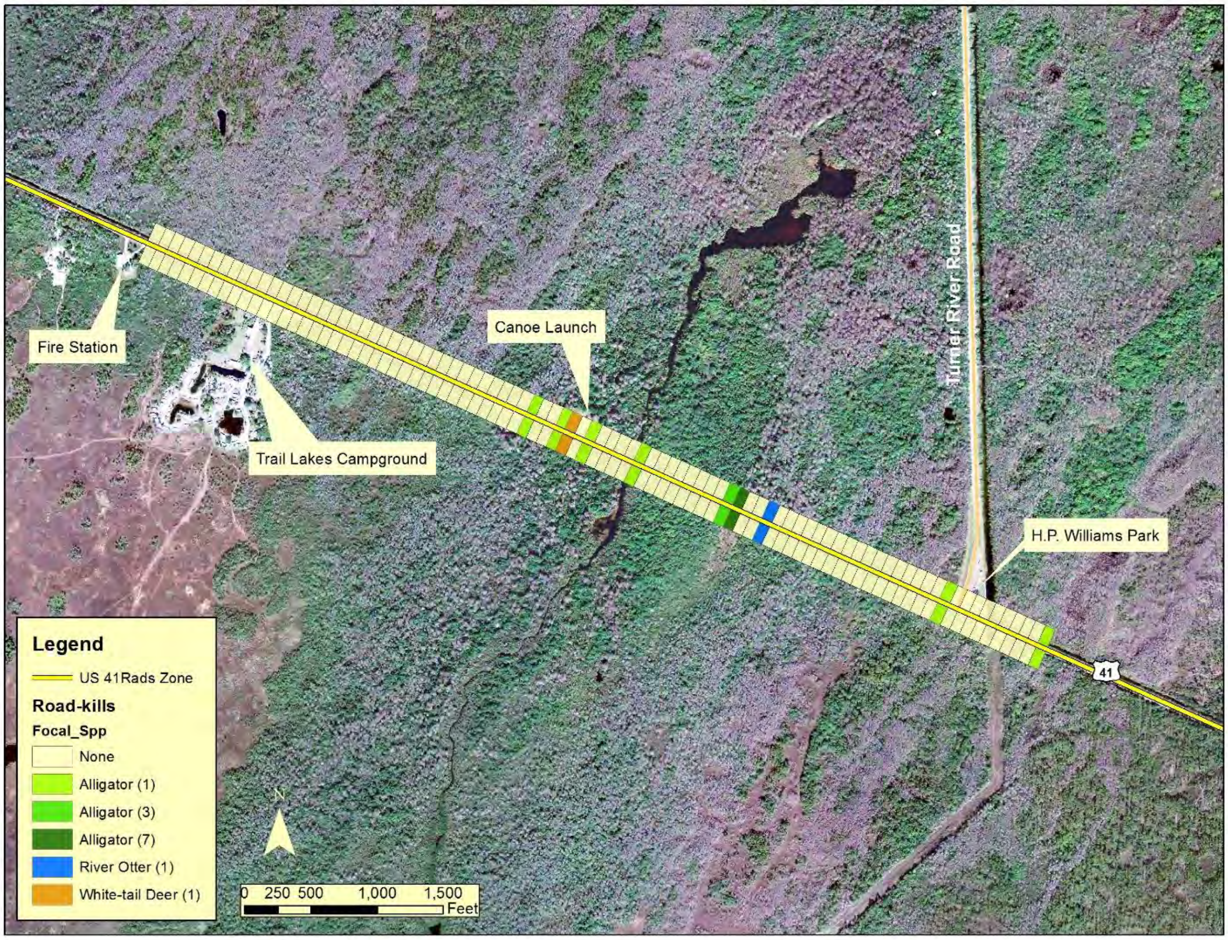

Figure 13. Location of other Focal Species Mortalities from Vehicle Collisions, Jan 2013 to Apr 2015. Note: road segments displayed equal 25 m (82 ft) in road length.

Track bed #s 2 and 3 are located on the southside of US 41 across from and slightly west of the entrance to Turner River canoe launch and were constructed across two abandoned driveways to a privately owned out-parcel. Several tracks of bobcat (n=52), Florida black bear (n=24), coyote (n=35) and white-tail deer (n=21) were recorded and to a lesser extent Florida panther (n=10) (Table 2). While white-tail deer may be only browsing on the grass on the roadside, the other species may be crossing the road and using the driveway to the canoe launch. A camera was installed across this paved driveway.

Track bed #5 is directly across the road from the Turner River canoe launch. This was a fairly small track bed and was used primarily as a secondary monitoring measure to supplement trail cameras placed in this area. Some use by bobcat (n=4) and Florida black bear (n=5) was observed and likely crossed the road using the paved entrance to the canoe launch (Table 2). Track bed #4 is on the northside of US 41 to the east of the canoe launch entrance and lies above a drainage swale area and the ramp to the canoe launch (fig. 11). This location, consequently has a high volume of public use. It is common for people to walk across the track bed (Table 2, n=540) to get to the road and look over the Turner River Bridge. Despite this high human presence, there is still use of the area by most target species, e.g., Florida panther (6), bobcat (7). We suspect the high number of meso-mammals (n=306; raccoons and Virginia opossum) is to scavenge around the picnic area and canoe ramp.

Table 2. Summary of Tracks Observed at Track Bed Stations on US 41, Feb 2013 to Apr 2015.

Species	Track Bed 1	Track Bed 1a	Track Bed 2	Track Bed 3	Track Bed 4	Track Bed 5	Total	%
RADS								
American alligator	1	0	0	1	0	0	2	0.1%
Florida panther	43	1	0	10	6	1	61	3.6%
bobcat	52	16	18	34	7	4	131	7.7%
Florida black bear	26	8	10	14	1	5	64	3.7%
coyote	4	5	17	18	9	2	55	3.2%
Canidae	7	3	5	14	4	0	33	1.9%
white-tail deer	20	33	5	16	5	3	82	4.8%
river otter	0	0	0	0	0	0	0	0.0%
long-legged birds	40	2	1	1	5	0	49	2.9%
subtotal	**193**	**68**	**56**	**108**	**37**	**15**	**477**	**27.9%**
NON-RADS								
other birds	19	1	12	28	17	1	78	4.6%
meso-mammals	184	13	7	13	78	11	306	17.9%
domestic animals	1	1	1	2	1	0	6	0.4%
humans	202	0	39	44	540	15	840	49.2%
subtotal	**406**	**15**	**59**	**87**	**636**	**27**	**1230**	**72.1%**
total	**599**	**83**	**115**	**195**	**673**	**42**	**1707**	

Notes: Refer to fig. 7 for location of track bed stations; RADS indicates target species that would trip RADS sensors, Non-RADS are non-target species that normally would not trip RADS sensors (except humans). Detailed species lists are provided in Appendix A.

Seasonal variation in track observations is shown in fig. 14. Florida panther tracks were recorded in all months except Aug and Sep. Most Florida black bear tracks were recorded in Nov to Jan. Bobcats were prevalent most months, though the majority were observed in fall-early winter. White-tail deer and canid observations oscillated from season to season.

Infra-red Trail Camera Monitoring – Camera trap stations are shown in fig. 9. At Trail Lakes landbridge north, a terrestrial connection over the northside canal, we recorded the highest use by Florida panther (n=45), Florida black bear (n=25), bobcat (n=81) and long-legged birds (n=54) (Table 3; fig. 15, TLLB North). As with the track data, we also recorded significant presence of humans at this site (n=839). Despite the high visitation of humans by day, our observations indicate that these landbridges are important crossing locations for mammals because the canal parallel to US 41is choked with hydrilla and other aquatic vegetation when full of water, which would make it difficult to traverse while swimming. A large number of meso-mammals were recorded (n=217), as was the case with track bed #1.

On the southside of US 41 at Trail Lakes landbridge, we recorded much less movement by Florida panther, Florida black bear and bobcat within the RADS sensor zone (Table 3; TLLB SE). This is likely because the sensor zone ends east of the landbridge allowing many animals crossing US 41 at this location to circumvent the RADS sensors and not be detected (Table 3; TLLB SW). As an example, we have recorded panthers crossing US 41 traveling south to north beyond the last sensor pole on the southside and undetected (fig. 16).

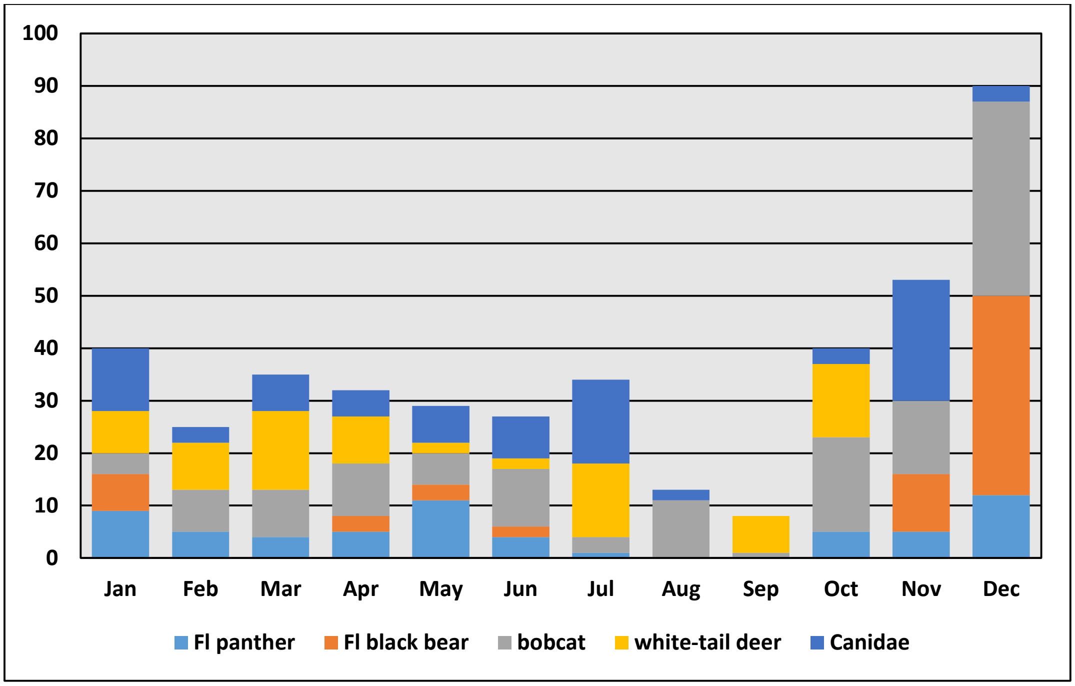

Figure 14. Tracks of Target Species Observed by Month from Feb 2013 to Apr 2015.

Table 3. Summary of Images Recorded at Camera Trap Stations on US 41, Feb 2013 to Apr 2015.

Species	TLLB N	TLLB SE	TLLB SW	TRCL driveway	TRCL N	TRCL SE	TRCL SW	TRR N	TRR S	Total	%
RADS											
American alligator	1	0	0	1	1	1	0	1	1	6	0%
Florida panther	45	8	4	15	9	4	0	0	10	95	5%
Bobcat	81	47	41	31	22	30	5	4	19	280	14%
Florida black bear	25	14	13	3	1	4	0	0	3	63	3%
Coyote	3	20	15	8	9	18	2	3	3	81	4%
Canidae	0	3	3	0	0	0	0	0	0	6	0%
white-tail deer	20	722	471	12	22	89	4	0	58	1398	70%
long-legged birds	54	5	4	1	2	6	0	0	10	82	4%
Subtotal	**229**	**819**	**551**	**71**	**66**	**152**	**11**	**8**	**104**	**2011**	**34%**
NON-RADS											
other birds	15	31	29	3	36	6	0	0	31	151	4%
domestic animals	5	24	16	1	2	8	1	0	1	58	1%
meso-mammals	217	58	54	35	253	267	104	3	271	1262	32%
humans	839	158	144	22	802	313	15	0	130	2423	62%
Subtotal	**1076**	**271**	**243**	**61**	**1093**	**594**	**120**	**3**	**433**	**3894**	**66%**
Total	**1305**	**1090**	**794**	**132**	**1159**	**746**	**131**	**11**	**537**	**5905**	

Notes: TLLB = Trail Lakes land bridge, TRCL = Turner River canoe launch, TRR = Turner River Road; RADS indicates target species that would trip RADS sensors, Non-RADS are non-target species that normally would not trip RADS sensors (except humans); Sites TLLB SW, TRR N and TRR S are outside the RADS zone so would not be detected.

White-tail deer and coyote were far more prevalent on the south than on the north side of the landbridge crossing. This is likely due to the attraction the open right-of-way on the southside of US 41 presents for browsing or hunting. Of special note, this data demonstrates that any of the target species traveling north across US 41 within TLLB SW (Table 3), would not be detected by RADS and therefore subject to greater risk of vehicle collisions.

The Turner River canoe launch location also exhibits significant crossing activity by target species (fig. 9). We monitored two sensor sections on the northside of the road and one sensor section on the southside of the road. The northside sensor sections consisted of the driveway to the Turner River canoe launch (fig. 17) and the landbridge adjacent to the canoe ramp (fig. 11). Most panther activity (n=15) at the canoe launch location was recorded at night on the paved driveway (Table 3; TRCL Driveway). Many bobcats (n=31) were also recorded using the driveway and even white-tail deer used it as an access point for crossing US 41 (n=12).

The landbridge at Turner River canoe launch (Table 3; TRCL North; fig. 11), to the east of the driveway, was also used by Florida panther (n=9), bobcat (n=22), coyote (n=9) and white-tail deer (n=22). As explained in the results for tracks at this location, human and meso-mammal presence was high (n=802 and n=253, respectively). On the southside of US 41 across from the Turner River canoe launch (Table 3; TRCL SE and SW; fig. 10), we captured several images of white-tail deer (n=93), bobcat (n=35) and coyote (n=20) on trail cameras. Human and meso-mammals were also recorded in abundance (n=328 and n=371, respectively).

Figure 15. Florida Panther Crossing over the Canal at Trail Lakes Landbridge on the Northside of US 41. Note: In our photographs and videos, we frequently observed panthers looking for oncoming traffic prior to crossing US 41.

Figure 16. Florida Panther Crossing US 41 from South to North on 1/7/14. Note: this panther would have been undetected by RADS since the sensor zone ends on the southside east of the Trail Lakes landbridge where it crossed.

The Turner River Road site lies outside the RADS sensor zone. Despite this fact, it nevertheless was significant to monitor because it provides a connection over the canal that runs parallel to US 41 on the northside of the road and vehicle use is minimal, particularly at night. Most observations of target species crossing the road have occurred where it is easiest to traverse the canal. Cameras placed on either side of US 41 at Turner River Road captured images of animals using this location (fig. 9). On the northside, a camera aimed across Turner River Road recorded very few animals (Table 3; TRR N, fig. 18), though many that cross the road at this site at night likely move through H.P. Williams Park. Unfortunately it wasn't practical for us to monitor the park with cameras.

Figure 17. Florida Panther on the Driveway to Turner River Canoe Launch.

On the southside of US 41 at Turner River Road, we captured more images within the camera trap array of animals attempting to cross the road or browse/hunt along the roadside (Table 3; TRR S). For example, we recorded 10 Florida panthers, 19 bobcats, 3 Florida black bears, and 58 white-tail deer. None of these would have been detected by RADS. A number of meso-mammals (n=271) were also present at this site that likely scavenge at the roadside park and people (n=130) are known to commonly walk out to the bridge and over to the southside of the road from the park. We also recorded one live observation of a Florida panther crossing US 41 just west of the Turner River Road.

Seasonal variation in photographs captured on camera traps is shown in fig. 19. Consistent with the track data, Florida panthers were recorded in all months except Aug and Sep. Most Florida black bear tracks were recorded in Oct to Jan. Bobcats were prevalent most months, though the majority were observed from May-Oct. White-tail deer activity spiked in January and again in September but to a lesser extent, and canid observations were more common from May to Jul.

Figure 18. A large Alligator Caught on Camera at H.P. Williams Park Walking on Turner River Road toward US 41. Note: This animal would not be detected by RADS because the sensor zone ends west of the Turner River Road intersection.

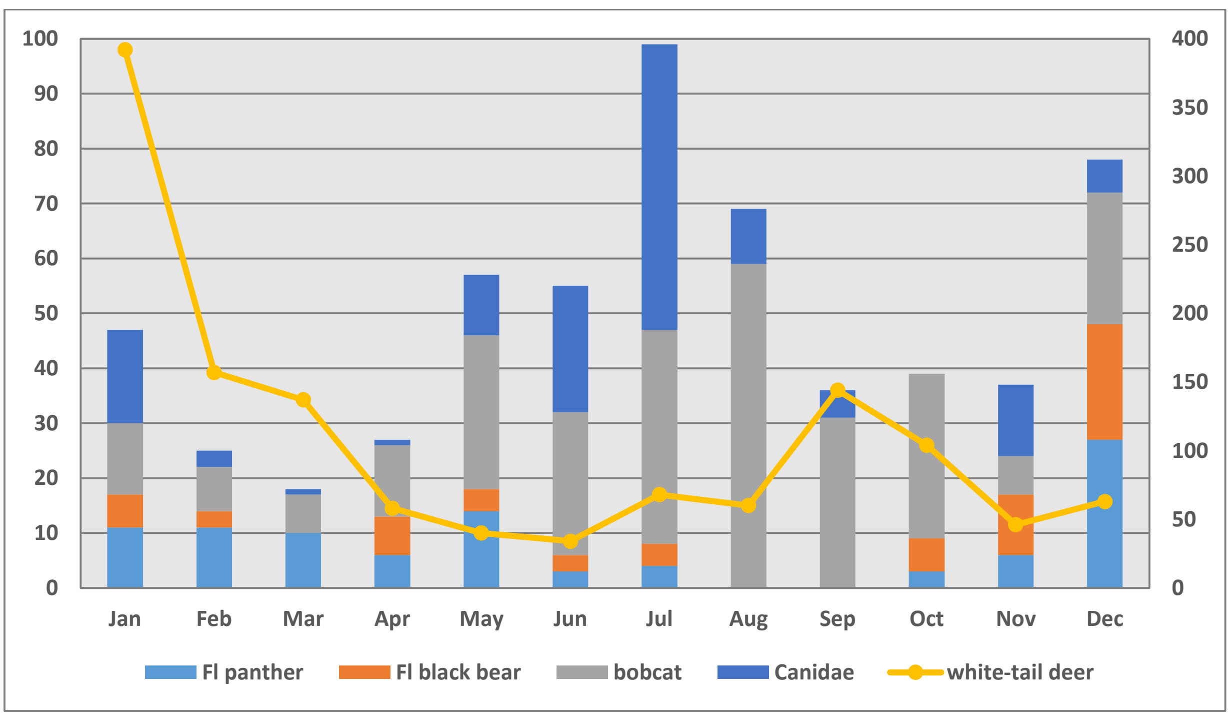

Figure 19. Images of Target Species Captured on Camera Traps by Month from Apr 2013 to Apr 2015. Notes: For monthly values of white-tail deer follow the righthand vertical axis, for monthly values of all other species follow the lefthand vertical axis.

B. Animal Detection: Comparison of Camera and Sensor Logs (US 41)

Camera data was further used to evaluate performance of the RADS sensor array on US 41 in accurately and reliably detecting the target species movements. This involved performing a comparison of RADS sensor logs and camera trap photographic records of animal movements.

Methods

We deployed infrared trail cameras in 5 strategically located sensor sections: S-D06-W, N-D07-W, S-D17-E, N-D19-E, and N-D19-W (fig. 20). See methods in section on Animal Presence: Road-kill, Tracks and Images for camera trap array setup and procedures used for checking and maintaining the cameras. By using the trail cameras as a monitoring device of each sensor section, we could compare date/timestamps of photographic data to sensor logs to tabulate:

1. **Successes:** the number of times that an animal passed in front of the RADS sensors and was detected
2. **False negatives:** the number of times that an animal passed in front of the sensors and was not detected
3. **False positives:** the number of times that the RADS was triggered without an animal there

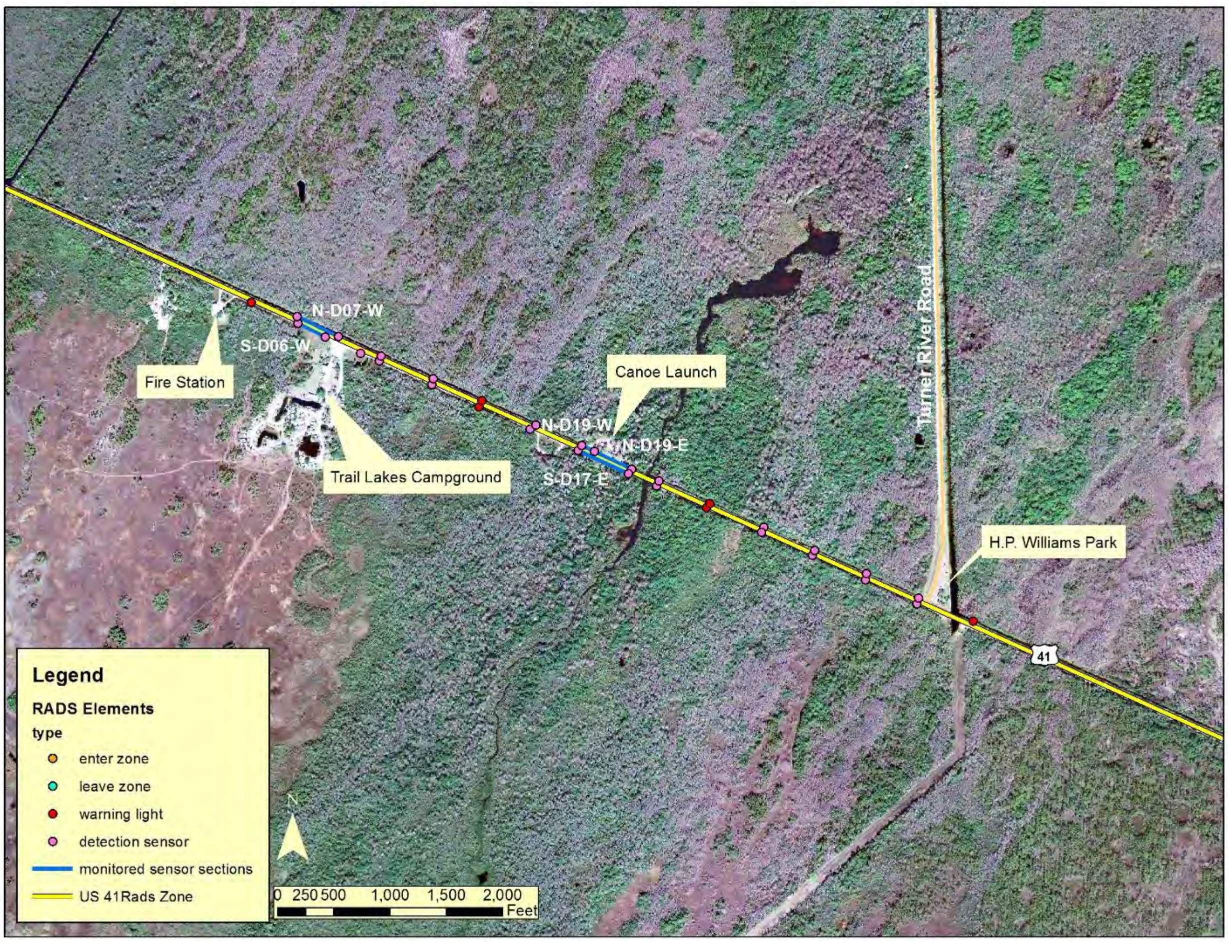

Figure 20. Monitored Sensor Sections Used for Assessing RADS Detection Reliability.

Procedures for data processing including reducing the amount of data to that necessary to identify the three options described above. First, data (date, time, camera number, sensor section, and species) from photographic images was entered into a spreadsheet. Second, the camera data was reduced to include only animals large enough to trip RADS sensors (at least 18" from the ground). Finally, the camera data was checked carefully to remove duplicates before analysis, once using a Microsoft Excel function and second by manual review.

Data for all sensor sections in text file format was downloaded monthly from the on-site RADS Linux computer. Prior to performing the matching analysis, we reduced the sensor data to only include sensor sections where camera trap arrays were installed. Next, all extraneous records were removed and only those records of sensor triggers (times when the infrared beam was broken) retained. Because we observed that the majority of animal activity occurred near or after dark, we further restricted our analysis to data collected from 1 hour before sunset to 1 hour after sunrise. In addition, any times that the RADS was offline were excluded from matching (Table 4).

Table 4. List of Times that Monitored Sensor Sections Were Off-line.

Location	Sensors affected	Date offline	Date restored	Notes from Simrex/Transcore/Transfield (pers. comm. Karen Alton)
Turner River Canoe Launch	N-D19-W	5/26/2014	8/26/2014	The pole was struck down (in front of the Trail Lake Canoe Launch area) on 5/26/2014 and repaired on 8/26/2014.
Turner River Canoe Launch	N-D19-W, N-D19-E	12/24/2013	1/23/2014	During inspection on 1/23/2014, a dead battery was replaced at site 19. Because it is uncertain when the battery died, a data gap may exist. It was working okay on the previous inspection of 12/24/2013.
Trail Lakes Land Bridge	S-D06-S	7/30/2014	8/24/2014	During inspection on 8/24/2014, a loose fuse was found at site 6 and reinserted. Because it is uncertain when this occurred, a data gap may exist. It was okay on the previous inspection of 7/30/2014.
Turner River Canoe Launch	N-D19-W, N-D19-E	11/29/2014	12/30/2014	During inspection on 12/30/2014, a loose fuse was found at site 19 and reinserted. Because it is uncertain when this occurred, a data gap may exist. It was okay on the previous inspection of 11/29/2014.

General Note: There was a system-wide data gap in sensor logs from Aug 2nd to Sep 11th 2014 due to a malfunction of the main computer.

The camera and sensor data were matched using a code developed by M. Grace in program R, vers. 3.0.1. (R Statistical Foundation for Computing 2013). The program matched camera and sensor data by date and time (accurate to three minutes). If there was no match, the program registered the data record as "na", allowing us to identify and count the number of false negatives and false positives.

Results and Discussion

Overall, the RADS performed from poor to fair in detecting animals large enough to trip the beam; the individual sensor sections that we monitored had average success rates between 10.7% and 66% (Table 5). Sensor sections N-D07-W (Trail Lakes Landbridge) and S-D17-E (southside of US 41 across from Turner River Canoe Launch) performed the best at 66% and 54% success rate, respectively. All other sensor sections monitored, exhibited less than a 50% success rate. More distressing is that on average from 34% to 89.3% of target animals were not detected, resulting in false negatives (i.e., the system did not activate in response to an animal). The percent false negatives are equivalent to 100 minus the success rate (Table 5). No significant monthly or seasonal effect on false negatives was observed (Tables 5 and 6, Appendix B-1).

Table 5. Camera Trap Data and Sensor Triggers by Sensor Section (Apr 2013 – Apr 2015). Data showing how well RADS sensors detected animal movement matched against camera data across the entire study period. Success rate is the percent of total images that matched sensor triggers across all months for each sensor section; false positive rate equals the percent of total sensor triggers not represented by image-sensor matches across all months for each sensor section (Appendix B-1).

Sensor	Total images	Total sensor triggers	Image-sensor matches	Success rate (%)	False positive rate (%)
N-D07-W	282	20,419	186	66	99.1
N-D19-E	64	4,484	25	39.1	99.4
N-D19-W	59	8,510	16	27.1	99.8
S-D06-W	75	157	8	10.7	94.9
S-D17-E	70	541	38	54.3	93

* There was incomplete coverage by cameras monitoring sensor sections S-D17-E and S-D06-W until mid-May 2014, so averages are from June 2014 onward.

The results of our monitoring show that RADS is generating a large percentage of false positives, that is, activating when no animal is present to trip the beam (Tables 5 and 6). Overall, 99.2 percent of all RADS activations fall into this category. There appears to be no monthly or seasonal pattern to these false positives (Table 6); nor does it appear there is any significant difference by sensor section (Table 5). Performance by month is erratic with some months displaying reasonably high detection rates (success rates of 80% or better) and other months unacceptably low (12 of 25 months at or below 50% in success rate), but no seasonal effects are present. In general, the results are too inconsistent and fall below the suggested minimum standard for detection success of 91% (Huijser et al. 2009). Despite periodically acceptable detection rates, false positive rates were consistently above 90%, irrespective of the month or season. In controlled tests, Huijser et al. (2009) reported false positive rates of less than 1% for nine different systems and recommended a maximum false positive rate of 10%. Obviously, on US 41 this is something that needs to be drastically reduced for the system to be effective in alerting drivers of any "real" danger on the road.

Several possibilities exist to explain the high level of false positives including obstruction of the sensor beam by vegetation or other debris, and by small animals climbing inside the apertures of each enclosure. Other possibilities include adverse response to environmental extremes in rainfall, humidity, high winds, heat and solar incidence (the latter only applicable during daylight hours). Lastly, interference by multiple transmitter units on subsequent receiver units and other unknown electronic or mechanical malfunctions. The problem is likely multi-causal in nature. It is also possible that our cameras did not capture every animal that may have triggered the beam, but even so, it is unlikely that enough large animals crossed the road to account for the extremely high number of triggers (Tables 5 and 6). Further, redundancy was used in camera trap arrays and track beds to capture any large animals that could be missed if a camera malfunctioned. It is highly unlikely this could be the issue, as the sheer number of total triggers for RADS sensor sections tested to that of number of total recorded images from camera arrays was 62 times higher (34,111 to 550).

The resulting effect is that the large number of false positives could be desensitizing drivers to the RADS. If the RADS is constantly flashing and animals are not present, they may begin ignoring the warning system. This effect may help explain possible differences in RADS effectiveness when comparing results of the driving simulator experiment to the field experiment conducted on US-41. Although in both experiments, activation of RADS warning lights caused a reduction in speed, the effect was greater in the simulator experiment (see figs. 29 and 33). It is important to note, however, that even with the large number of false positives, our field experiment showed that the RADS does offer some benefit, especially during tourist season (see fig. 29).

Table 6. Camera Trap Data and Sensor Triggers by Month (April 2013 – April 2015). Data showing how well RADS sensors detected animal movement matched against camera data by month for all sensor sections. Success rate is the percent of total images that matched sensor triggers of all sensor sections by month; false positive rate equals the percent of total sensor triggers not represented by image-sensor matches of all sensor sections by month (Appendix B-1).

Month	Year	Total images	Total sensor triggers	Image-sensor matches	Success rate (%)	False positive rate (%)
April	2013	23	435	23	100	94.7
May	2013	14	2,557	13	92.9	99.5
June	2013	15	422	5	33.3	98.8
July	2013	14	151	1	7.1	99.3
August	2013	19	449	5	26.3	98.9
September	2013	27	1,383	16	59.3	98.8
October	2013	13	1,183	8	61.5	99.3
November	2013	34	473	26	76.5	94.5
December	2013	35	870	6	17.1	99.3
January	2014	12	611	9	75	98.5
February	2014	27	1,519	22	81.5	98.6
March	2014	13	3,648	10	76.9	99.7
April	2014	10	2,546	8	80	99.7
May	2014	18	1,190	0	0	100
June	2014	8	189	1	12.5	99.5
July	2014	34	269	23	67.6	91.4
August	2014	10	2	0	0	100
September	2014	14	595	1	7.1	99.8
October	2014	26	762	1	3.8	99.9
November	2014	40	7,187	33	82.5	99.5
December	2014	30	860	16	53.3	98.1
January	2015	57	821	15	26.3	98.2
February	2015	41	2,532	23	56.1	99.1
March	2015	14	2,284	7	50	99.7
April	2015	2	1,173	1	50	99.9

*data from some months were partially missing because of mechanical or electronic system failures.

Further exploration of the performance of the system is shown in Table 7. As previously mentioned, we restricted our analysis to a daily period of 1 hour before sunset to 1 hour after sunrise when most animal activity occurred. Another reason it was necessary to restrict our analysis to this time period was because the number of non-animal triggers during the day was so high, it was not practical to evaluate performance during the day. The number of triggers during the day outnumbered those at night by a 3:1 margin. From January 2013 to April 2015, over 1.8 million triggers were registered in daylight hours compared to about 690,000 at night (Table 7). During our study, the system was observed flashing all day long on most occasions. This was obviously related to system malfunctions, for even if our recorded observations of 550 total target animals for the 5 sensor sections monitored were extrapolated out to all sensor sections (n=26; Appendix B-2), it would not remotely approach the magnitude of system triggers that were occurring.

Table 7. Total Triggers by Sensor, Jan 2013 – Apr 2015. A comparison of RADS sensor triggers, day vs. night. For detailed account of sensor triggers by month, see Appendix B-2.

Sensor	Total Day	Total Night	Total Triggers	% at Night
N-D07-W	92,312	34,950	127,262	27%
N-D10-E	149,828	60,577	210,405	29%
N-D10-W	59,695	18,642	78,337	24%
N-D14-E	129,655	50,567	180,222	28%
N-D14-W	385,971	84,941	470,912	18%
N-D18-W	35,322	42,484	77,806	55%
N-D19-E	26,960	7,886	34,846	23%
N-D19-W	65,729	4,213	69,942	6%
N-D25-E	61,255	9,805	71,060	14%
N-D25-W	193,583	42,703	236,286	18%
N-D29-E	141,216	41,628	182,844	23%
N-D29-W	63,423	13,559	76,982	18%
N-D33-W	83,220	29,438	112,658	26%
S-D06-E	20,767	687	21,454	3%
S-D06-W	3,322	280	3,602	8%
S-D09-E	12,067	6,876	18,943	36%
S-D09-W	105,166	132,404	237,570	56%
S-D13-E	7,940	3,021	10,961	28%
S-D13-W	17,871	8,955	26,826	33%
S-D17-E	3,108	620	3,728	17%
S-D17-W	8,398	549	8,947	6%
S-D24-E	18,078	5,707	23,785	24%
S-D24-W	159,097	86,047	245,144	35%
S-D28-E	1,581	292	1,873	16%
S-D28-W	3,872	1,595	5,467	29%
S-D32-W	3,286	937	4,223	22%
Total	**1,852,722**	**689,363**	**2,542,085**	**27%**

Contrarily, the system appeared to function correctly more often during most night observations. Only 27% of system triggers occurred at night (Table 7). We decided to examine the difference in night vs. day triggers in more detail, in particular if RADS triggers changed over time. We looked at the total number of triggers in all sensor sections per month.

The number of triggers appeared to increase over time for many sensor sections (see Appendix B-2), so the data were natural log-transformed to assess whether this trend was statistically significant using linear regression. The total amount of triggers did increase slightly over time (Fig. 21a; regression analysis: B= 0.0323, t= 2.15, p= 0.0427, adjusted R2 = 0.136, d.f.= 22). This trend seems to be driven by an increase in nighttime triggers over time (Fig. 21b; regression analysis: B= 0.0362, t= 2.25, p= 0.0374, adjusted R2 =

0.145, d.f.= 22) because there was not a significant increase in daytime triggers over time (Fig. 21c; regression analysis: B= 0.0305, t= 1.86, p= 0.077, adjusted R2 = 0.096, d.f.= 22). However, it is interesting to note that there were many more daytime triggers than nighttime triggers overall (Table 7, Appendix B-2).

Some sensors registered more triggers than others:

- N-D14-E recorded over 470,000,
- 4 sensors registered over 200,000,
- 4 sensors logged over 100,000,
- 5 sensors had over 50,000,
- 8 sensors logged more than 5,000, and
- only 4 sensors had less than 5,000

Certain months more triggers occurred than others:

- over 100,000 occurred in Mar and Apr of 2013 and 2014, and Oct and Nov of 2014,
- over 50,000 occurred in 16 other months, and
- only 5 months had less than 50,000 triggers

Because this is an integrated system of 26 separate sensors connected to a single warning mechanism, a malfunction registered by one sensor reflects on the performance of the entire system. As such, the general trends discussed above underlie many malfunctions at specific times by specific sensors. For example, some sensors appeared to perform similarly on a continual basis (S-D06-W, S-D32-W), while others seemed to display more triggers over time (N-D14-W, S-D24-W), and yet others declined over time (S-D06-E, S-D09-W) or only displayed one or a few months of high triggers (S-D09-E, N-D10-W).

To further explore possible seasonal effects and change in rainfall, we performed a linear regression of number of triggers and success rate against rainfall/month (figs. 22a and 22b). The results (Table 8) indicate that there is a non-linear negative relationship between precipitation and the number of triggers- more precipitation is correlated with fewer triggers. This relationship, though significant, is small. No association between precipitation and RADS success rate (percentage of pictures of animals matched by RADS triggers) was detected (Table 9).

False positive rate and precipitation could not be compared using regression methods, since the vast majority of false positive rate values were above 95% (see Table 6) which created a skewed dataset that could not be transformed. Instead we chose to evaluate the relationship using a categorical statistic, the chi-squared test, rather than a linear analysis. The data was divided into the following categories: >90% false positive rate or <90% false positive rate, and >5 in. precipitation and <5 in. precipitation. The chi-squared test identified if large amounts of false positives (>90%) were associated with >5 in. precipitation or <5 in. precipitation. This relationship was insignificant (χ2=1.83 on 1 d.f.; p= 0.176).

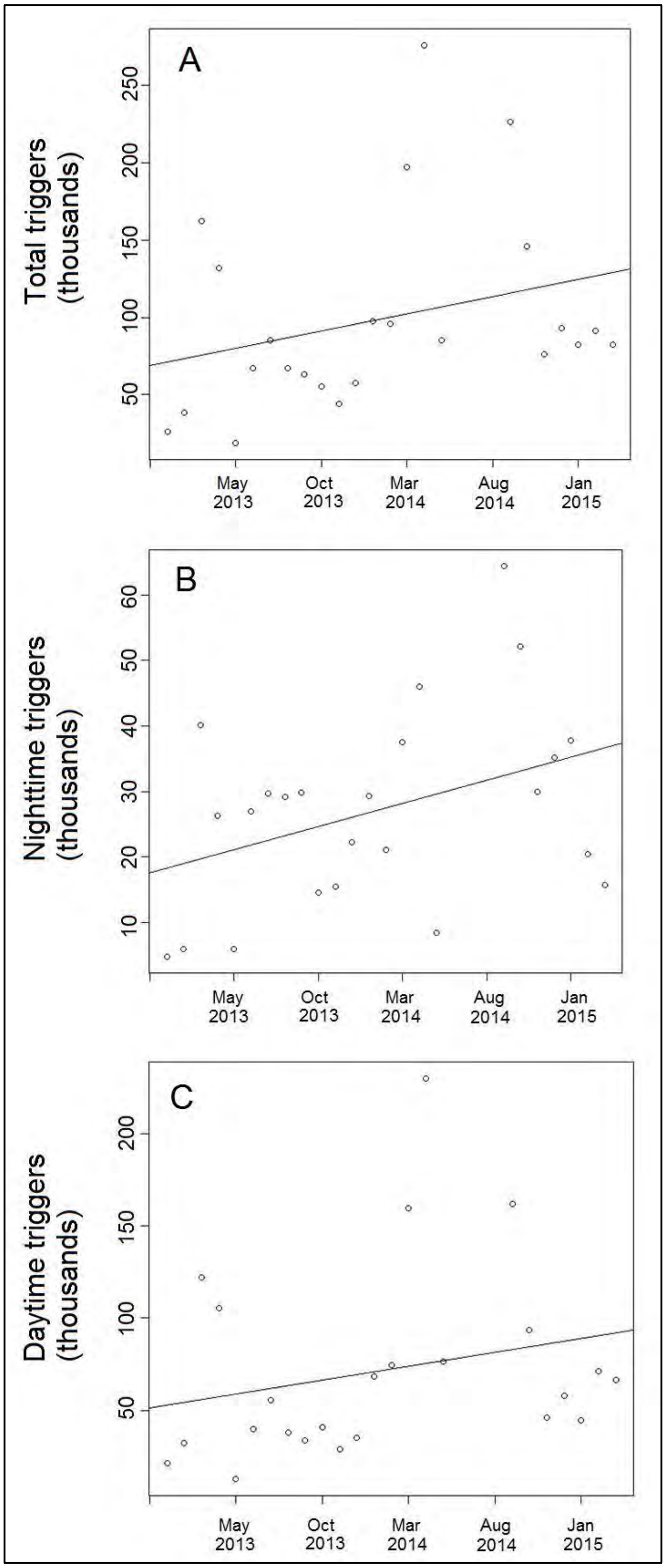

Figure 21. An Analysis of Night vs. Day Triggers of the RADS System over Time. Each dot represents data from every month between Jan 2013 and Apr 2015. Trigger totals by month for each sensor are shown in Appendix B-1.

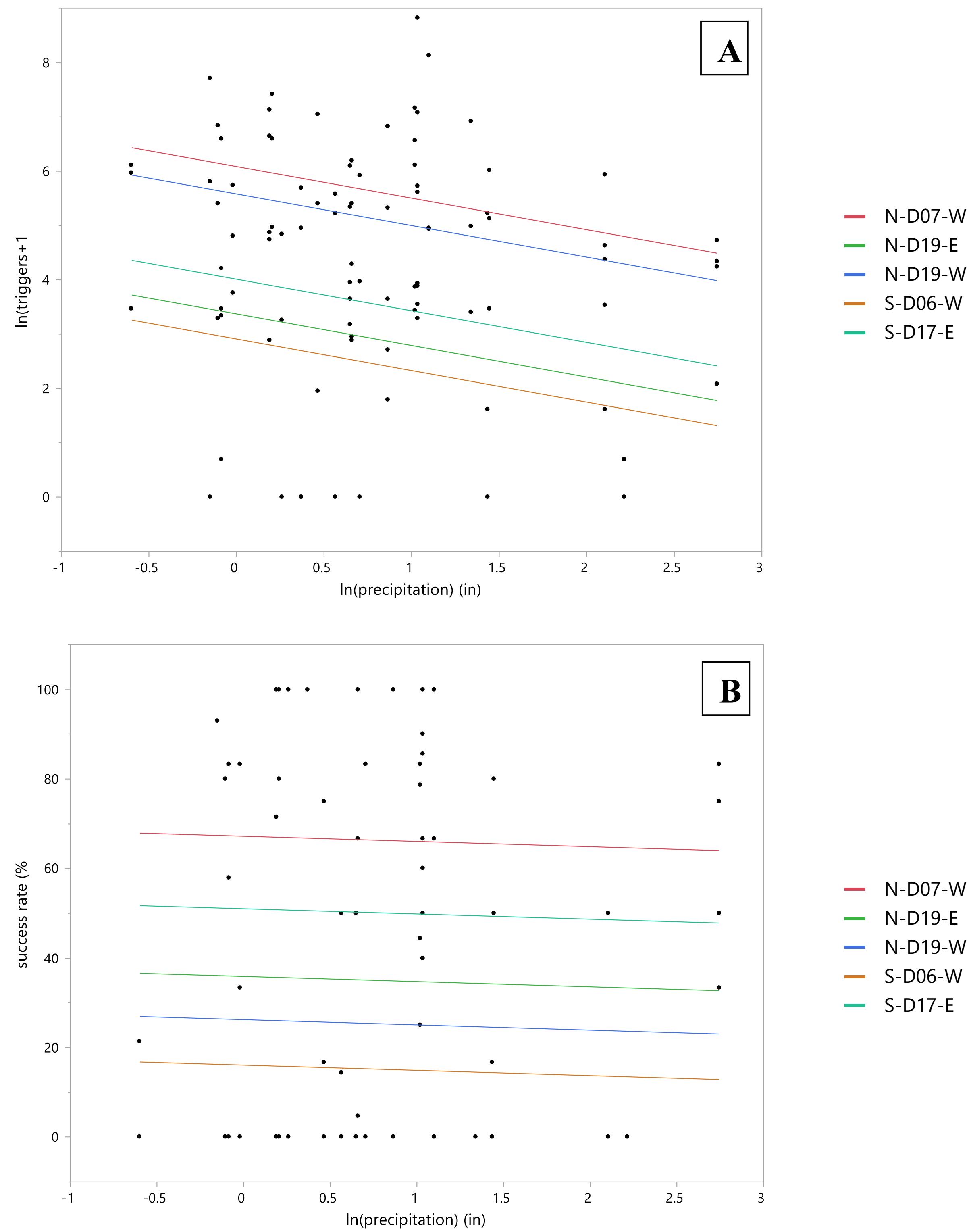

Figure 22. Number of Triggers/Month (A) and RADS Success Rate (B) Regressed against Rainfall/ Month. Number of triggers and precipitation were natural-log transformed to ensure homogeneity of variance/ residuals; +1 was added to number of triggers to account for zero values in the data.

Table 8. Results of Regression of Triggers/Month against Precipitation. A transformation of ln(x+1) was applied to number of triggers to ensure evenness of residuals.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.39	0.288	15.2	<.0001*
ln(precip)	-0.582	0.227	-2.56	0.0120*

Table 9. Results of Regression of Success Rate/Month against Precipitation.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	39.3	6.57	5.98	<.0001*
ln(precip)	-1.17	5.65	-0.210	0.837

Based on our tabulations from observations of target animals that cross US 41 within the RADS sensor zone, nearly all sensors are malfunctioning more often than is acceptable. We recommend a complete and detailed system evaluation to identify all causal mechanisms that result in malfunctions and implementation of such measures as to correct these. It is critical to eliminate the current magnitude of false positives if the system is expected to have the intended result of significantly reducing animal-vehicle collisions.

The RADS system should produce a recommended minimum standard for reduction in animal-vehicle collisions of 71% (Huijser et al. 2009). Unfortunately, we were unable to determine the overall reduction in collision rate with targeted species because aside from data on Florida panther and Florida black bear, no pre-installation data existed on road-kills. Regarding Florida panther, 6 collisions occurred within the RADS sensor zone over 13 years prior to installation of the RADS system, 2 collisions were recorded in 2012 (the first year it was activated), but none occurred in the subsequent 2.3 yrs we monitored the system. In raw numbers, pre. vs. post installation, a negligible increase of 0.1 collisions per year occurred. However, we believe it is far too brief a time to evaluate change in collision rate, particularly considering that the two collisions, post-installation, occurred in the first year and none thereafter. Regarding Florida black bear, no road-kills were recorded previous to or during this study within the RADS sensor zone; however 2 black bear road-kills were recorded within 4 mi of the sensor zone.

C. Animal Detection: Comparison of Camera and Sensor Logs (Control Site)

A control site was included as part of the experiment to evaluate detection reliability of the RADS sensors. The use of a control site allowed us to eliminate significant confounding factors observed at the US 41 site (and discussed in Section B above) that negatively affected performance (e.g., vegetation growth, vehicular and pedestrian traffic along the roadside).

Methods

The study site selected was near UCF in Orlando adjacent to SR 46 within Seminole State Forest. We chose a location next to a wildlife underpass used by a relatively large number of the target species to obtain significant sample size (fig. 23). Although the Florida panther isn't included in the subset of target species at this location, black bear, white-tail deer, bobcat, coyote and wild turkey are common. We set up a single sensor section 150 ft in length within a cleared firebreak across the entrance to the wildlife underpass (fig 24). The sensor beam was mounted approximately 18 in above ground, the same clearance as the RADS on US 41. An array of six trail cameras that provided overlapping coverage of the area was installed to monitor and verify animal passage through the RADS sensor zone (fig. 24).

Since the cameras all faced the same direction and overlapped in range, it was necessary to remove any "duplicates" of the same individual animal and multiple animals when captured on more than one camera with the same time stamp. This was required to accurately match RADS triggers. Because certain animals often exhibited prolonged presence on camera (in particular browsing white-tail deer), the matching window was extended to +3 min. That way, if an animal was caught on camera prior to the sensor being triggered, it could still be matched. After 3 minutes, adding more time did not make a difference in matches.

Results and Discussion

Long delays in obtaining RADS sensor equipment from Simrex reduced our test period to 5 months, December 2014 through April 2015. Shortly following installation and testing of the system, an operating system malfunction corrupted the recorded data file. Unfortunately this problem wasn't discovered until the end of the study period. Data recovery efforts conducted by Simrex resulted in the retrieval of useful data from 12/11/14 to 3/5/2015.

Target and non-target animals captured on camera traps is shown in Table 10. Target species included bobcat (39), Florida black bear (4), coyote (18), gray fox (1), white-tailed deer (157), wild pig (2) and wild turkey (18). Non-targets included smaller meso-mammals (27), humans (43) and horseback riders (43); the latter two being large enough that they were included in the detection reliability analysis. The majority of target species recorded occurred in December and January (fig. 25). Of the 325 total images of animals and humans/horseback riders that would trip the RADS sensor, only 198 were independent and used in the matching analysis.

The RADS control sensor detected 137 of 198 independent animals large enough to trip it, a 69.2% success rate. This means that 61 of 198 (30.8%) were not detected and classified as false negatives. A total of 247 triggers were logged by the RADS; given that only 137 were matched to animal crossings, this equates to a 44.5% false positive rate (110 of 247). Success rate and false negative values are within the same range as the best performing sensors of the US 41 RADS; yet false positive rate was significantly lower in the control experiment, but still above the recommended 10% rate. Because of the shortened evaluation period and data corruption issues, this test was unable to clearly distinguish performance in a control setting from that on US 41. It was further complicated by presence of trespassing horseback riders and occasional hikers that were not anticipated at the control site. We would recommend additional testing of the system in a control setting in conjunction with any plans to modify the system on US 41, since it could serve as a baseline of the best achievable performance for this system and to help troubleshoot and anticipate potential problems with the US 41 application.

Figure 23. SR 46 RADS Control Site Location: A. Aerial View. Sensor array (shown in red) was located within the northside firebreak along SR 46 in Seminole State Forest in Lake County (cleared of vegetation and within an area of limited public access). **B. Facing West.** Transmitter-receiver units were placed across the entrance of a wildlife underpass (red circle indicates location of infra-red transmitter at the eastern end of the sensor zone).

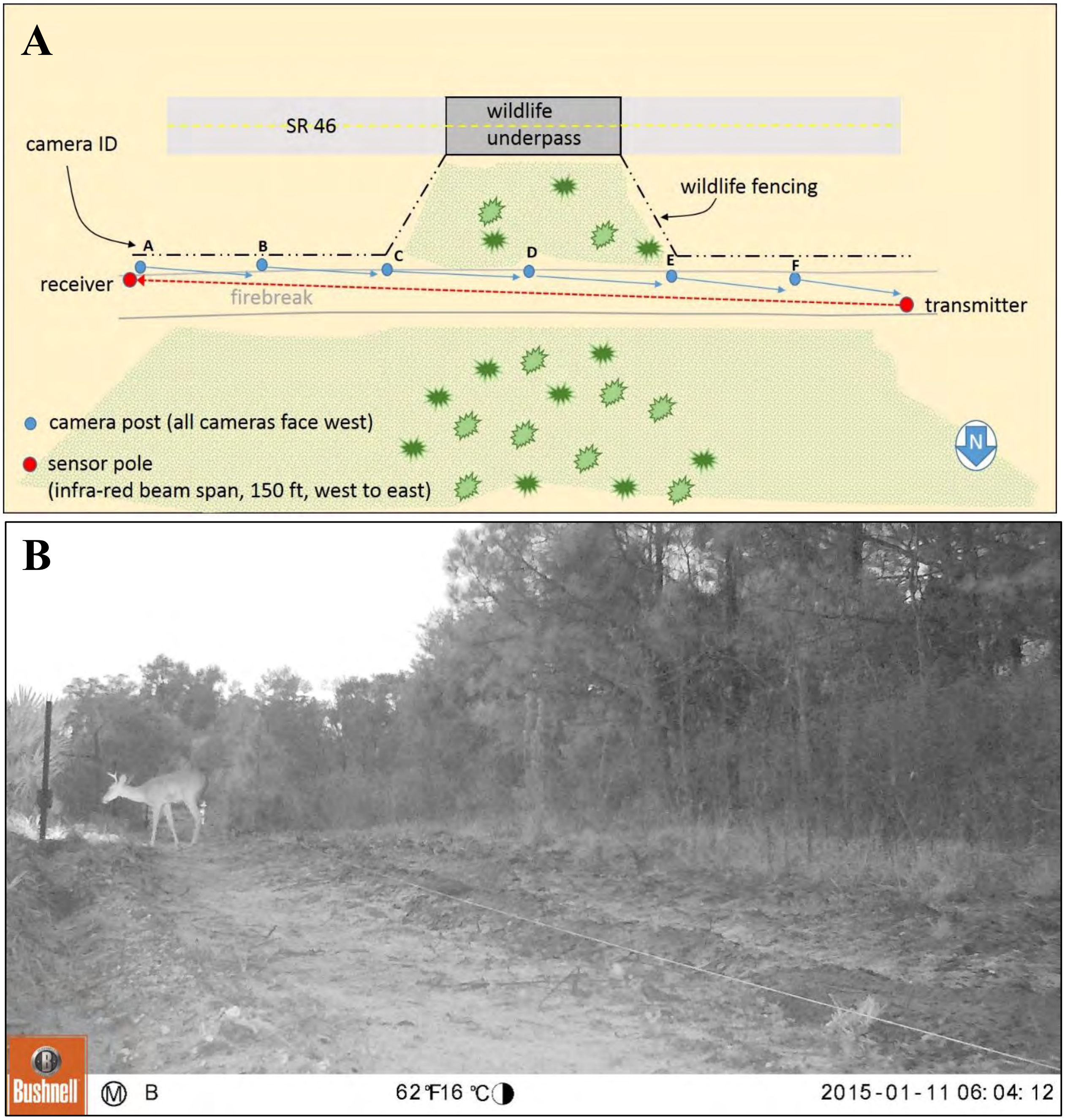

Figure 24. SR 46 RADS Control Site Setup. A. Site Design. The sensor beam was aimed west to east across the entrance of the wildlife underpass; An array of 6 trail cameras facing west were used to confirm animal trespass. **B. System Operation.** When target animals walked through the firebreak, they would “break” the sensor beam; trigger date/time was simultaneously recorded on the system log. Monitoring cameras (with overlapping range) captured the animal on still shot and video and recorded date/time of the event. The site was an area of high animal traffic at a wildlife crossing in central Florida. Target species included black bear, white-tailed deer, coyote, bobcat and wild turkey.

Table 10. Summary of Images Recorded on Camera Traps at Control Site, 12/11/14 to 3/5/15.

Species	Total
RADS	
bobcat	39
Florida black bear	4
coyote	18
gray fox	1
white-tail deer	157
wild pig	2
wild turkey	18
Subtotal	239
Non-RADS	
meso-mammals	27
horseback rider*	43
humans*	43
Subtotal	113
Total	352

*non-targets that would also trip the sensor

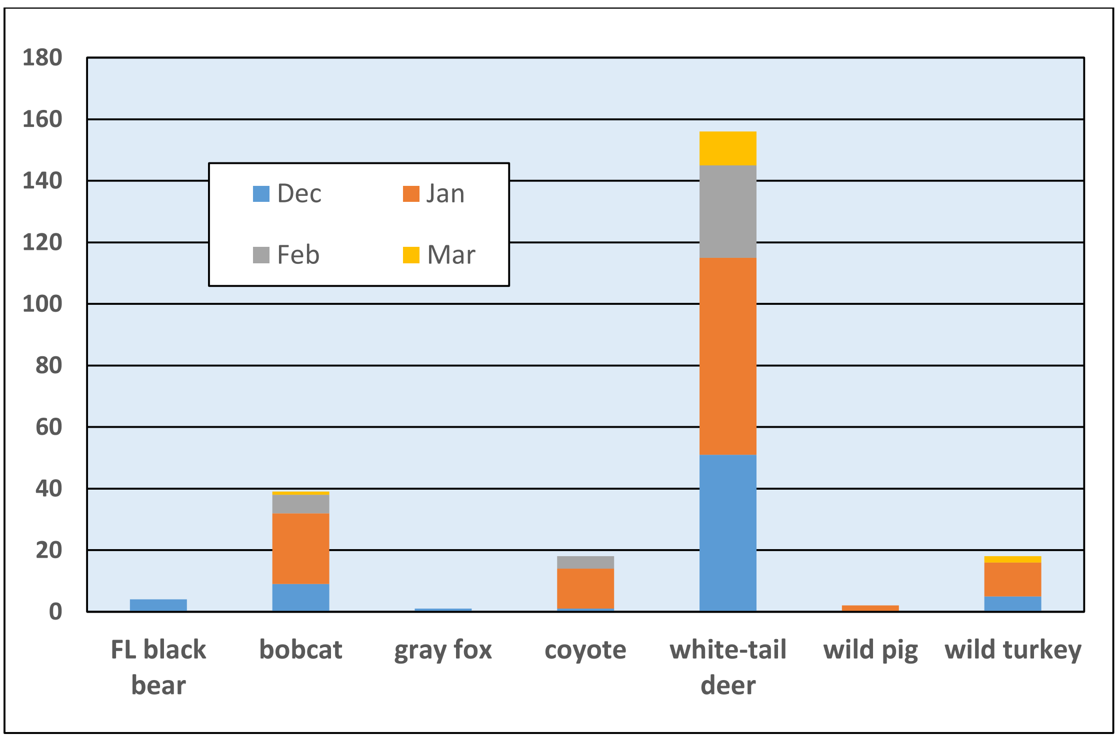

Figure 25. Images of Target Species Captured on Camera Traps by Month from Dec 2014 to Mar 2015.

D. Driver Response: Vehicle Speed/Driver Response Analysis

As part of the evaluation of system effectiveness we performed an on-site experiment to determine driver response (potential change in vehicle speed) to RADS warning signs/signals.

Methods

To assess driver response to RADS, we measured the speed of individual cars on US 41 when the RADS was active (flashing) and inactive (not flashing). Vehicles traveling east and west were both included. We also recorded daily traffic counts for four consecutive days for each of the four periods we measured vehicle speed. Initial vehicle speed was recorded using traffic counters placed at a location 0.3 mi before drivers encountered any RADS signs (control measurements). Drivers were not able to see the signage or warning lights associated with the system from this distance, even when active. We used IRD Mini TRS traffic counters with twin tubes to record speed and vehicle type. Resulting experimental vehicle speed was recorded in the center of the RADS zone, by which point drivers would have been exposed to two RADS warning signs (flashing or not). Vehicle speed in the center of the RADS zone was recorded using Bushnell Velocity DSP Speed Guns (accuracy to +/- 1 mph). Figure 26 displays the site layout for the experiment.

Figure 26. Site Design of the RADS Vehicle Speed Experiment. The project limit (highlighted in red) shows the road length covered by RADS sensors (RADS zone). The two black “X”s to the east and west of the array represent locations where initial vehicle speed was recorded before drivers entered the RADS zone (control data). The black “X” in the center of the RADS zone is the location where resulting experimental vehicle speed was recorded. Figure modified from FDOT RADS Fact Sheet (2014).

We recorded speeds from 1609 cars over 4 time blocks from 2014 to 2015. The first two time blocks were during the off-season, when traffic was mostly local: May 14-17 and Sep 24-27 of 2014. The second two blocks were during the tourist season, with a high volume of out-of-town visitors: Dec 3-6 of 2014 and Feb 11-14 of 2015. Data collection took place during twilight and at night, times of day when target species activity was greater. In some cases, manual switching was required on our part to balance the number of vehicle exposed to RADS warnings light on vs. off.

To ensure that each vehicle’s speed was independent, the raw data were sorted and groups of 2 or more cars in close proximity and going the same speed (+/- 2 mph) in the same minute were grouped together. All but the first car recorded in that group were excluded from analysis. The person censoring the data, did so blind to the status of the RADS system (on or off). We also excluded cars with trailers, buses, motorcycles, RVs, and semi-trucks in the analysis because there were too few of these. Vehicles analyzed were passenger cars, pickup trucks, and vans. This resulted in a reduced data set of 1309 vehicles.

Experimental data analyses – To assess the effect of the RADS, we performed Analysis of Variance (ANOVA) on our experimental speed data and our control speed data using the following factors: whether or not the RADS was active (flashing) when speed was recorded, season (tourist season or off-season), time of day (twilight vs. night) and their interactions. To meet the assumptions of ANOVA, all groups (Table 11) were checked for homogeneity of variances (F tests; JMP 11) and visually inspected for normality. Some outliers (> 3 standard deviations away from the mean) were excluded from analysis in order to meet these assumptions.

Table 11. Number of Vehicles per Treatment Combination.

RADS on				RADS off			
twilight		night		twilight		night	
tourist	local	tourist	local	tourist	local	tourist	local
205	138	195	196	206	73	165	131

Control data analyses – The control data and experimental data were analyzed separately because different methods were used to obtain each, therefore they are not directly comparable. However, we would expect to see no effect of the RADS in the control group, whereas if the RADS is effective at changing driver speed, we would expect to see an effect in the analysis of the experimental data.

The same analysis was used on the control data as on the experimental data. Control data groups were visually inspected and found to be normal. F tests for homogeneity of variances (JMP 11) found that variances of speeds between seasons were unequal. However, since there are fewer data points in the tourist season, and the tourist season showed smaller variance, this makes ANOVA a more conservative test, less likely to detect differences between the means. If we see an effect of season, therefore, it will be a strong effect.

Results and Discussion

Traffic volume was recorded with traffic counters during the four time periods that speed surveys were conducted (Table 12). Traffic counters were set to record continuously for the four days of each speed survey period (two weekdays and two weekend days). Average number of vehicles per hour in the February survey period was more than twice that of the other three periods, indicative of peak tourist season. December was only slightly higher than the May and September survey periods.

Experimental data – The overall model including the effects of RADS, season, and time of day was significant ($F_{7, 1287} = 12.95$; $p = 3.581e-16$). Interaction effects were found at the $\alpha = 0.1$ significance level between RADS and season and time of day (twilight vs. night) and season (Table 13).

Because significant interactions were present, these were investigated first with a whole-model post-hoc test (Tukey's Honestly Significant Difference; figs. 27 and 28). First, we report the findings on the interaction between RADS and season (off-season or tourist season; fig. 27). In the tourist season, the activation of the RADS caused a significant difference in vehicle speed (2.37 mph slower with the RADS on; Tukey's HSD, $p = 1.14 \times 10^{-4}$); however, this effect was not seen during the off-season, when local traffic made up the bulk of cars tested (0.914 mph slower with RADS on; Tukey's HSD, p= 0.540). This is an interesting result, considering that when the RADS was turned off, drivers in the tourist season drove significantly faster than drivers in the off-season (2.17 mph; Tukey's HSD, p= 0.00697). As would be expected, drivers in the tourist season drove faster with the RADS off than drivers in the off-season with the RADS turned on (3.08 mph; Tukey's HSD, p= 7.0 x 10^{-7}).

Table 12. Seasonality of Traffic on US-41 in Big Cypress National Preserve. These values represent the average number of vehicles per hour based on 24 hour monitoring for 4 consecutive days per month using a traffic counter. Daily number of cars/hr was computed and then averaged across the 4 days to produce an average and standard deviation.

Month	Direction	Average # Vehicles/Hr	Standard Deviation
May-14	EB	46.1	22.4
	WB	42.1	18.2
Sep-14	EB	36.9	17.0
	WB	40.1	14.9
Dec-14	EB	50.6	13.0
	WB	47.2	5.04
Feb-15	EB	104	70.8
	WB	55.4	38.0

Table 13. ANOVA for Driver Speed in the Center of the RADS Zone (after passing 2 active or non-active warning signs). "RADS" = whether the warning signs were flashing or not flashing; "TOD" = time of day (twilight or night); "season" = tourist season or off-season.

	d.f.	SS	MS	F	p > F
RADS	1	1190	1190	20.2	6.88 x 10^{-6}*
TOD	1	2964	2964	50.8	1.69 x 10^{-12}*
season	1	549	549	9.41	0.0022*
RADS*TOD	1	46	46	.791	0.374
RADS*season	1	168	168	2.89	0.0896†
TOD*season	1	172	172	2.94	0.0867†
RADS*TOD*season	1	155	155	2.65	0.104

* significant at $\alpha = 0.05$ † significant at $\alpha = 0.10$

There was also a significant interaction between season and time of day (Fig. 28). During the tourist season, drivers drove faster at twilight than at night (3.44 mph; Tukey's test, p< 1.0 x 10^{-6}). The same effect was observed in the off-season, though the difference was not as large (1.96 mph; Tukey's test, p= 0.0202). In addition, drivers in the tourist season drove faster than those in the off-season at twilight (2.13 mph; Tukey's test, p= 0.00577). Finally, tourist season drivers drove faster at twilight than off-season drivers did at night (4.10 mph; Tukey's test, p< 1.0 x 10^{-6}).

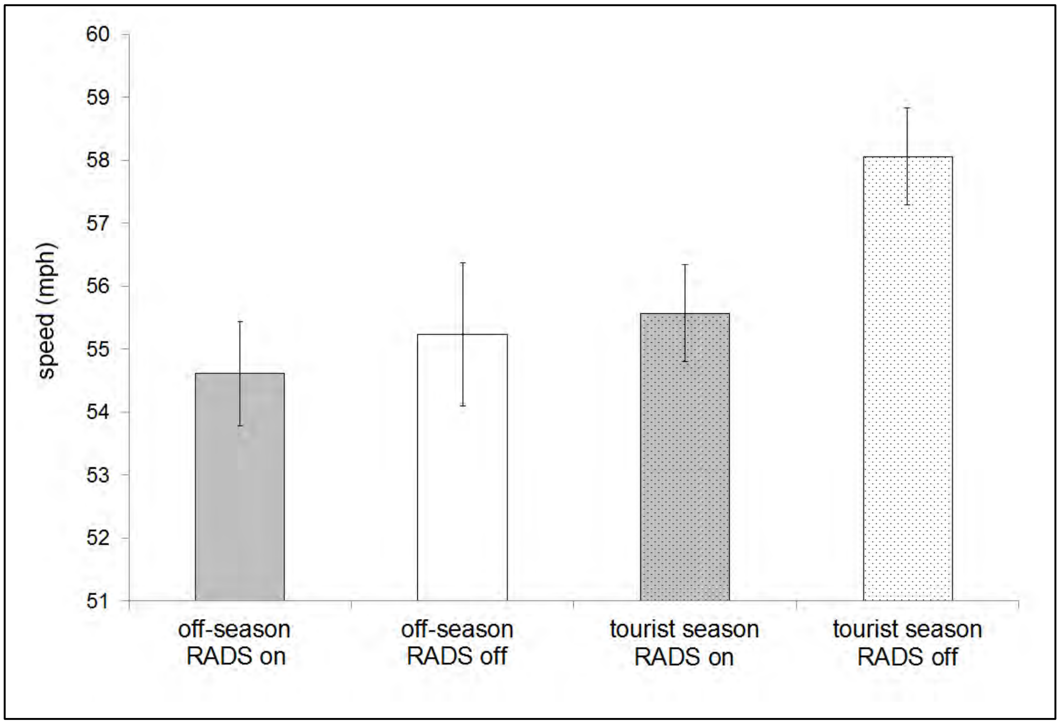

Figure 27. Interaction between RADS and Season on Vehicle Speed. Column height indicates group means, while error bars indicate 95% confidence intervals.

Control data – The overwhelming factor influencing speed is time of day (Table 14), an effect that was also observed in the experimental speed data, so it is unsurprising that it also affected speed outside the RADS zone. However, there was also an interaction observed between RADS, time of day, and season (significant at $\alpha = 0.10$), which despite its borderline p value ($p = 0.097$; Table 14), we investigated to be thorough using Tukey's HSD.

As expected, all twilight mean speeds were higher than nighttime mean speeds, with the exception of the contrast between tourist seasons with the RADS off, which was not significantly different between twilight and night ($p = 0.448$; fig. 29). This was the only sign of a seasonal effect, which was present in the results from within the RADS zone. This implies that the seasonal effect mainly becomes important once drivers have entered the RADS zone. This makes sense, since tourists and locals should have different levels of experience with the RADS system, but should have similar driving patterns on a stretch of unremarkable road.

More importantly—although there were a number of significant contrasts between the RADS on and RADS off groups, these contrasts were also always between twilight and night (fig. 29). This highlights the impact of time of day and suggests that there was no difference in driver speed outside the RADS sensor zone during the different periods of RADS activation. This is what we would expect, considering that drivers could not see the RADS signs at these locations, and reinforces the fact that the effect of the RADS we observed within the testing zone are true effects.

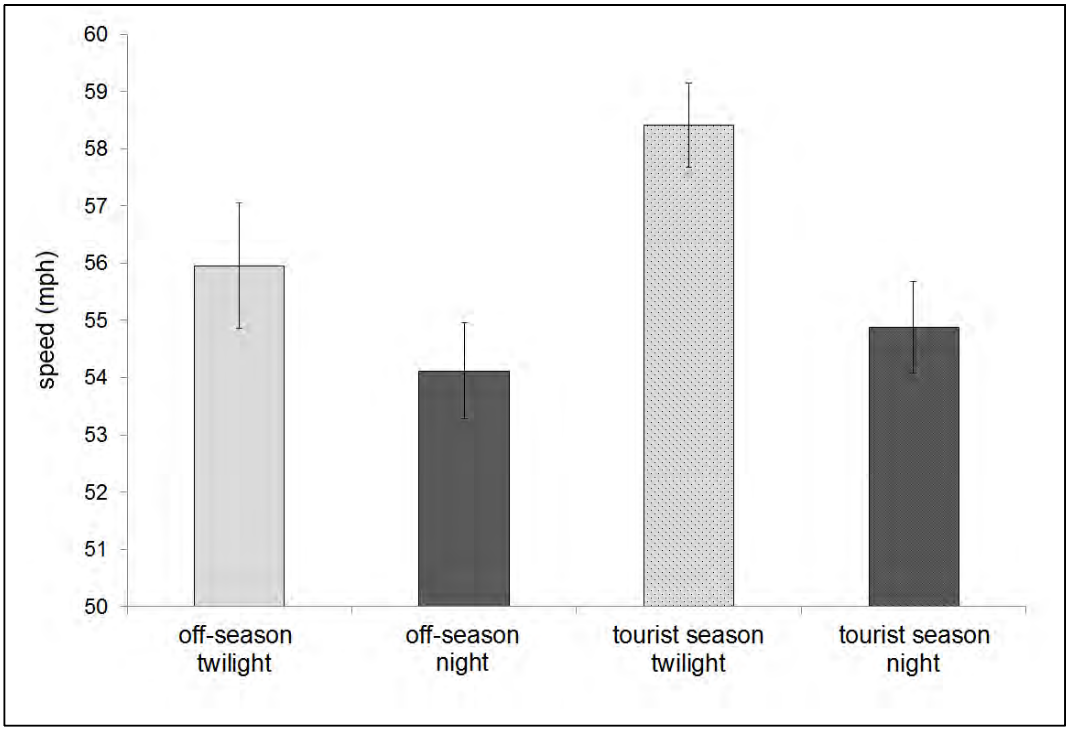

Figure 28. Interaction between Time of Day and Season on Vehicle Speed. Column height indicates group means, while error bars indicate 95% confidence intervals.

Table 14. ANOVA for Driver Speed at Control Points (prior to drivers encountering signs to inform or alert them to RADS). "RADS" = whether the warning signs were flashing or not flashing at the time; "TOD" = time of day (twilight or night); "season" = tourist season or off-season.

	d.f.	SS	MS	F	p > F
RADS	1	49	49	0.643	0.423
TOD	1	5214	5214	67.974	5.06×10^{-16}*
season	1	85	85	1.107	0.293
RADS*TOD	1	25	25	0.325	0.569
RADS*season	1	44	44	0.577	0.447
TOD*season	1	10	10	0.127	0.722
RADS*TOD*season	1	212	212	2.760	0.097†

* significant at $\alpha = 0.05$ † significant at $\alpha = 0.10$

One of the major interactions observed was between the activation status of the RADS and the season. Traffic observed during the off-season likely consisted mostly of local or regional residents, who had presumably observed the RADS multiple times before, if not daily, considering that US 41 is also a commuter route between Naples and Miami. Traffic observed during the tourist season would still contain local traffic, but would also include a higher percentage of drivers unfamiliar with US 41. Results from our driver questionnaire reflected this fact: during the off season, local and in-state residents made up 78.9% of responders, while in the tourist season, they only made up 20.5%.

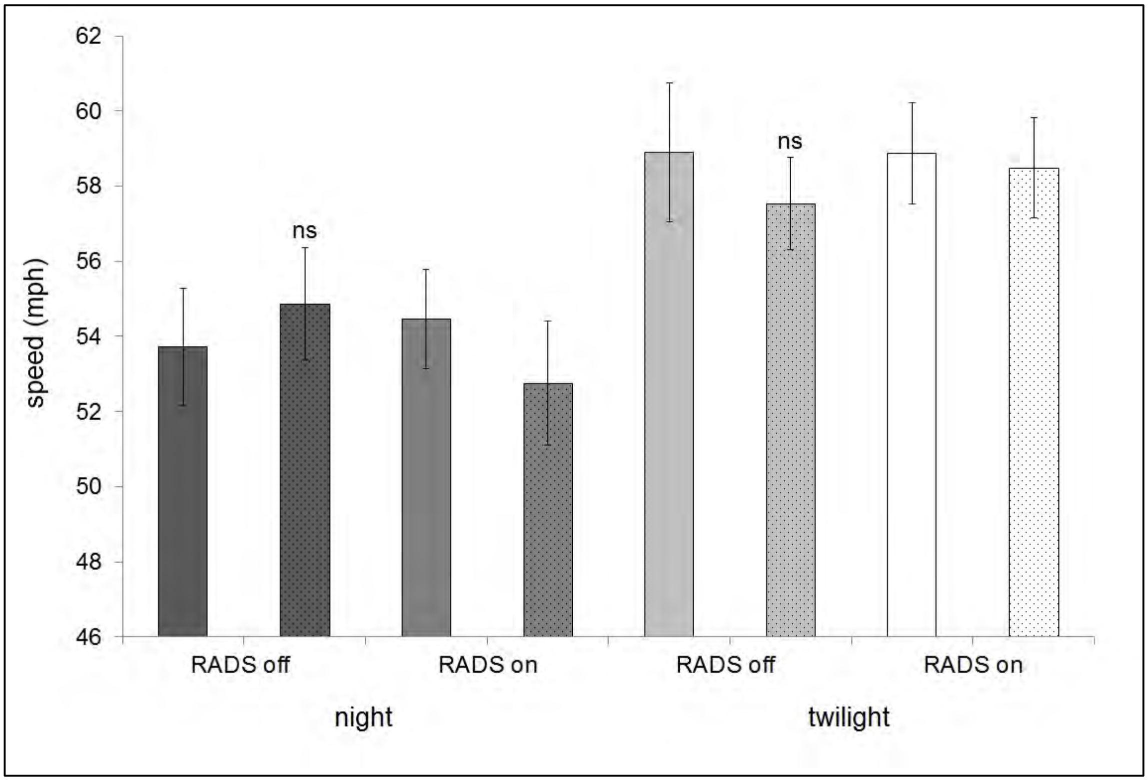

Figure 29. Interaction between Time of Day, Season, and RADS on Driver Speed before Entering the RADS Test Zone. Twilight group means are significantly greater than night group means (α= 0.05), except for the one contrast indicated by "ns." RADS status (warning lights on or off) outside the RADS sensor zone did not affect driver speed, as expected (drivers were unaware of the system at this location). Stippled boxes indicate the tourist season, while non-stippled boxes indicate the off-season. Column height indicates group means, while error bars indicate 95% confidence intervals.

Despite the fact that drivers in the tourist season generally drove faster than those in the off-season, tourist-season drivers responded to the RADS by driving more slowly, while off-season drivers did not. We suggest that this result is from acclimation by local drivers to the RADS. Throughout the experimental period, the RADS continually malfunctioned causing warning signs to flash almost nonstop during the day, though it appeared to work correctly at night. It is highly probable that local drivers, who were used to seeing the RADS lights flash constantly, had begun to disregard the warning system. However, non-local traffic would not have experienced the same acclimation.

There are two posted speed limits on US 41: daylight (60 mph) and night (45 mph). These different limits are intended to reduce risk of collisions with wildlife that are more active at night. During our testing period, we found that drivers in both the tourist and off-seasons drove faster at twilight than at night, which was expected given that some drivers would follow the daytime speed limit at twilight. It is interesting to note that although drivers slowed down at night, they still drove well above the speed limit of 45 mph (Fig. 28).

E. Driver Response: RADS Driving Simulation Experiment (modified from Grace et al. 2015)

In a controlled setting we conducted a driving simulator study to examine: 1) if the presence of advanced warning signs/signals has an effect on driver speed, latency to brake when an animal enters the road unexpectedly (treated here as a proxy for alertness), and/or the probability of animal-vehicle collisions, and (2) if word-based and picture-based warning signs perform differently. An advantage of this approach was that the driving simulator allowed for control of confounding environmental, electronic/mechanical system and maintenance variables that result in failure to perform in situ.

Methods

Driving simulator – The driving simulator was provided and programmed by the Research in Advanced Performance Technology and Educational Readiness Lab at the University of Central Florida's Institute for Simulation and Training. They created a digital version of the RADS installation on US 41. Using this digital version of the roadway and surroundings as a base, three alternatives were created: 1) without RADS warning signs (control), 2) with word-based RADS warning signs (same as on US 41), and 3) with redesigned, picture-based RADS warning signs (fig. 30).

Figure 30. Images of RADS Signs Used in the Driving Simulation. Left: replications of the US 41 RADS signs, Right: simulated designs of modified RADS warning signs that feature picture-based flashing warning signs and a picture-based informational sign.

Participants – Ninety people took part in the simulator experiment in Jul and Aug 2013. Participants included students and employees of UCF and residents of the surrounding community. All were at least 18 years old, and had been licensed to drive for at least one year. We established three age groups (1= 18–24 yrs, 2= 25–44 yrs, 3= 45+ yrs) and sought 30 participants from each. We recruited into these groupings to obtain a more balanced participant pool, and because age is known to affect driver behavior: young or inexperienced drivers make up a disproportionate amount of accidents because of an underdeveloped ability to recognize hazards and a tendency to overestimate their driving skills (reviewed in Deery 2000).

The required number of participants were based on an *a priori* power analysis of a 3-treatment ANOVA. To detect a moderate effect size with power = 0.8 and α = 0.05 required 35 subjects per group (n = 105). To detect moderately large effect sizes required fewer, 20 per group (n = 60). We assumed that we would be working with moderately large effect sizes, but chose to use a larger sample size (n=90) in case the effect was not as large as initially thought. Due to scheduling constraints in the RAPTER Lab (our collaborators in the College of Engineering that provided and hosted the simulator experiment), 90 was the maximum number of test subjects that was feasible.

Participants in each age group were assigned to a treatment (control, word-based RADS, or picture-based RADS) using a systematic random design: i.e., the first member of each age group tested was assigned to the control treatment; the second, word-based; third, picture-based; fourth, control, etc. Thus, exactly one-third of each age group was assigned to each treatment. Participants were told that they were participating in a study aimed at evaluating driver response to various road hazards. The true nature of the study was not disclosed to the participants until debriefing after the testing session. This eliminated the possibility of predetermined responses by participants.

Simulator experiment – Each participant completed six runs in the simulator, three "twilight" scenarios and three "night" scenarios. These periods were chosen because that is when collisions with large animals are more likely to occur (Danks and Porter 2010; Neumann et al. 2012), and also because in BCNP, there is a nighttime speed limit of 45 mph, while during the day (and twilight) the speed limit is 60 mph. Speed limit signs in the simulation used these same rates. Before participants began the six runs, they were provided an acclimation period to get accustomed to the simulator. A five-minute break was offered between each run. Each set of three runs included one target run featuring an animal hazard—specifically a deer entering the road directly in front of the vehicle at a certain point in the run. The other two were non-target runs that included different road hazards (either another car crashed on the roadside or a vehicle suddenly entering the road in front of the participant's vehicle). This approach prevented participants from recognizing the true purpose of the study. Each run featured only one hazardous circumstance. The six runs were presented in random order. Each run featured a 0.5 mi baseline distance to begin, a distance of 0.5 mi following the RADS informational sign, and a 1.3 mi length RADS zone. All hazards, animal or not, occurred within the RADS sensor zone. Driver speed and brake pressure were automatically recorded every 0.014 sec. Whether or not participants crashed into the animal hazard during target runs was also recorded.

Statistical analysis – Only the target runs involving an animal hazard were analyzed. Each participant completed one target run during the twilight scenario and one during the night scenario. Because each participant was tested both at night and twilight, which incorporated different speed limits, effects of these factors were tested using paired methods. All statistical tests were performed in JMP® (version 10, SAS Institute Inc., Cary, NC) and figures generated using JMP® or R Statistical Computing software (version 3.0.2, R Foundation for Statistical Computing 2013).

Pairwise comparisons between twilight and night – McNemar's chi-squared test for paired samples was used to assess whether a significant difference in crashes existed between runs occurring at twilight vs. those at night. To test if driver speed was greater at twilight than at night, a Wilcoxon's signed rank test (1-tailed) was used. The speed considered was the avg speed between the point where the participant entered the RADS sensor zone and the point just before the deer appeared in the road. We used a nonparametric test because the difference between the pairs was not normally distributed (Shapiro-Wilk test, $W = 0.953$, $p = 0.00260$). To test if there was a difference in latency to brake (measured as the distance between the location where the participant started braking and the location of the deer on the road) between night and twilight, we again used Wilcoxon's signed rank test (1-tailed) (Shapiro-Wilk test, $W = 0.945$, $p = 0.00131$). Participants excluded included six who did not brake in response to the animal hazard in one or both target runs, four from control treatment, one each from word- and picture-based treatments, three from age group 1 and three from age group 2.

Effect of RADS – To assess whether treatment or age had an effect on crash probability, we fit a multiple logistic regression model using "crash" (yes/no) as the dependent binomial result and treatment (control, word-based RADS, and picture-based RADS) and age group as fixed factors. We intended to perform this analysis for both twilight and night, but so few crashes occurred at night ($n = 2$) that the model became unstable and uninformative. Instead, the analysis was applied to twilight only. We used One-Way

Analysis of Variance (AVOVA) to assess whether treatment or age had an effect on speed or latency to brake (measured as the distance between the location where the participant started braking and the location of the deer on the road). Separate ANOVAs were executed for twilight and night datasets.

Results and Discussion

Descriptive statistics – We tested 43 women and 47 men. Mean age (yrs) and standard error was 20.4 ± 1.98 (range 18–24) for age group 1; 30.3 ± 4.45 (range 25–41) for age group 2; and 52.2 ± 5.62 (range 45–65) for age group 3. Of the 90 participants, 30 crashed (Table 15).

Table 15. Number of Crashes per Factor.

Factor	Number of crashes			
Treatment	Control	Word-based	Picture-based	Total
	18	8	4	30
Age group	Age group 1	Age group 2	Age group 3	Total
	18	6	6	30
Time of day	Twilight	Night		Total
	28	2		30
Gender	Males	Females		Total
	13	17		30

Pairwise comparison of crashes occurring in twilight vs. night runs – There were 30 total crashes observed in our experiment. During twilight runs, participants crashed 31% of the time (n = 28 crashes), while in night runs, participants crashed 2% of the time (n = 2 crashes). This difference was significant (McNemar's $\chi^2 = 22.3214$, DF = 1, $p < 0.00001$), thus we analyzed the effect of experimental factors separately for twilight and night. However, since only 2 crashes occurred at night, we only further analyzed crashes that occurred in twilight simulations.

Effect of RADS on crash rate – The overall model for crash probability was highly significant ($\chi^2 = 24.9$, DF = 5, $p < 0.0001$). The independent variables treatment and age group had a significant influence on crash likelihood (respectively, $\chi^2 = 17.5$, DF = 2, $p = 0.0002$; $\chi^2 = 7.08$, DF = 2, $p = 0.0290$; effect likelihood ratio tests). Between levels of experimental factors, participants in the youngest age group (age group 1) were significantly more likely to crash than those in the oldest age group (age group 3; Table 16). There was no significant difference in crash rate between age groups 1 and 2 or 2 and 3. Participants in the control treatment were significantly more likely to crash than those in the word-based treatment or the picture-based treatment (Table 16). There was no significant difference in crash rate between the word-based treatment and the picture-based treatment.

The simulation re-confirms the significant role that age plays in driver safety, with participants in age group 1 (the youngest age group) being much more likely to crash than participants in age group 3 (the oldest age group). The difference between age groups 1 and 2 was very close to being significant, and we believe that with a larger sample size of crashes, the difference would probably be significant. This trend highlights the need to educate younger drivers about the danger of animal-vehicle collisions.

Pairwise comparison of speed in twilight vs. night runs – Mean speed of participants during twilight runs was 58.2 mph ± 1.21 SE and ranged from 43–99 mph, compared to a nighttime average of 48.6 mph ± 1.24 SE with a range of 14–99 mph. Extreme outliers (>3 standard deviations from the mean) were seen in both twilight and night and were from the same participant; these were removed from further analyses. The average difference in speed between twilight and night runs for a participant was 9.6 mph ± 1.09 SE faster at twilight than night, with a range of -12.7–21.2 mph. This difference is significant (Wilcoxon signed rank test with continuity correction, W = 120, p < 1.0e-13).

Table 16. Crash Probabilities between Treatments and Age Groups. Odds ratios showing likelihood of members of the 1st group crashing compared to members of the 2nd group crashing. A dagger (†) indicates significant odds ratios at α= 0.10 while an asterisk (*) indicates effects significant at α= 0.05.

Comparison	Odds Ratio	p> χ^2	Lower 95%	Upper 95%
age group 1 vs. age group 2	3.54	0.0514†	0.993	14.1
age group 1 vs. age group 3	5.15	0.0114*	1.43	21.5
age group 2 vs. age group 3	1.46	0.591	0.36	6.06
control vs. word-based	6.29	0.0026*	1.85	25.4
control vs. picture-based	14.0	<0.0001*	3.59	68.9
word-based vs. picture-based	2.22	0.267	0.546	10.1

Effect of RADS on speed – The overall twilight model for speed was significant (F = 2.55, DF = 8 and 80, p = 0.0159). Both treatment and age group had a significant influence on speed, and there was no interaction between treatment and age group (Table 17). Between the different treatments, participants in the control treatment (mean speed 60.3 mph) drove significantly faster than those in the picture-based treatment (55.6 mph), but not the word-based treatment (57.3 mph) (Tukey-Kramer HSD, p = 0.0098 and 0.137, respectively; fig. 31). Participants in age group 3 drove significantly slower than those in age group 2 at α= 0.1 (Tukey-Kramer HSD, p = 0.0560) but there were no other significant differences between age groups (fig. 31). Nighttime speed data were transformed using the Box-Cox transformation to meet the assumption of normal residuals). The overall nighttime model was not significant (F = 1.75, DF = 8 and 80, p = 0.0991), and no factor significantly affected speed.

The reduction in mean speed at twilight from 60.3 mph in the control group to 55.6 mph in the picture-based group (4.7 mph difference) may seem small, but previous work shows that a change of this size could greatly reduce crash probability. In a meta-analysis of crash rates before and after speed limit changes on rural roads in Europe and the United States, Finch et al. (1994) fit a model predicting that with a 1 mph decrease in speed, there was a corresponding 5% decrease in crash rate. Taylor *et al*. (2002) also found that as speed increases, crash rate increases, and particularly concerning severe crashes: in their model, a 10% increase in mean speed on a roadway predicted a 30% increase in fatal and serious crashes. Hence, our observed differences in speed would result in tangible safety benefits for humans and wildlife.

Table 17. ANOVA for Average Speed of Participants within the RADS Zone at Twilight. An asterisk (*) indicates effects significant at α= 0.05.

Factor	DF	SS	F ratio	p > F
age group	2	211.4	3.19	0.0464*
treatment	2	327.0	4.94	0.00951*
age group*treatment	4	136.8	1.03	0.396

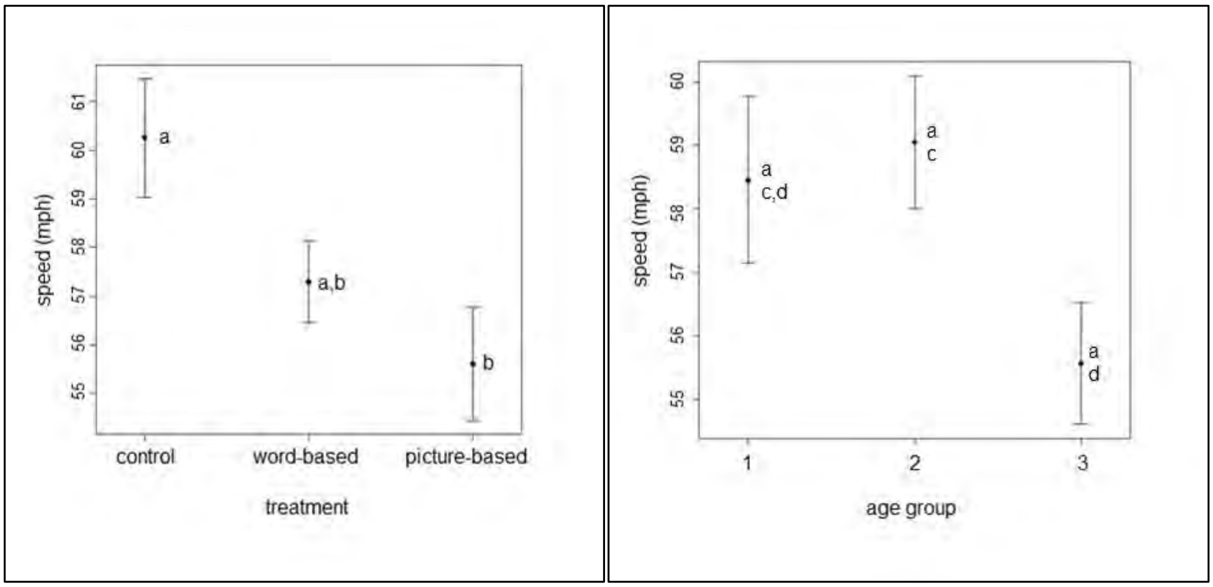

Figure 31. Participant Speed at Twilight by Treatment and Age Group. Mean and standard error of the speed (mph) of participants at twilight in: **Left**- the three treatments; **Right**- the three age groups. Significantly different treatments have different letters next to them (a and b indicate significant differences at α= 0.05; c and d indicate significant differences at α= 0.10). n=30 for word- and picture-based treatments; n= 29 for control after removing an outlier (>3 SD from the grand mean).

Pairwise comparison of braking distance in twilight vs. night runs – Mean braking distance during twilight runs was 150 ft before the deer's location on the road (±1.99 SE; range 47.2–261.8), compared to 169.6 ft during night runs (±1.81 SE; range 72.8–261.8). The average paired difference between night braking start distance and twilight braking start distance was that participants braked 19.6 ft earlier at night than twilight (±2.80 SE), though there was a very wide range (-188.3 ft–213.6 ft). This difference was significant (Wilcoxon signed rank test with continuity correction, W = 2350, p = 0.00274).

Effect of RADS on braking distance – Both the twilight and nighttime overall models were significant (F= 3.77, DF = 8 and 75, p = 0.0009 and F = 3.81, DF = 8 and 78, p = 0.0008, respectively; nighttime braking distance data were transformed using the Box-Cox transformation to meet the assumption of normal residuals). At twilight, braking distance was influenced by treatment, though the effect of age group was also significant at α = 0.1 (Table 18). There was no significant interaction between treatment and age. Participants in both the picture-based and word-based treatments began to brake earlier than participants in the control treatment (on avg, 26.5 ft and 24.9 ft earlier, respectively; Tukey-Kramer HSD, p = 0.0007 and p = 0.0017, respectively; fig. 32). There was no significant difference in braking distance between participants in the picture-based and word-based groups (Tukey-Kramer HSD, p = 0.968; fig. 32).

Table 18. ANOVA for Braking Distance. Distance was measured from the point where participants began to brake when the deer ran out in front of them during the simulation. Separate ANOVAs were calculated for twilight and night data. A dagger (†) indicates effects significant at α= 0.10 while an asterisk (*) indicates effects significant at α= 0.05.

time of day	factor	DF	SS	F ratio	p > F
twilight	age group	2	331.9	2.91	0.0605†
	treatment	2	1121.8	9.85	0.0002*
	age group*treatment	4	252.9	1.11	0.358
night	age group	2	110.4	2.16	0.122
	treatment	2	426.5	8.36	0.0005*
	age group*treatment	4	236.9	2.32	0.0643†

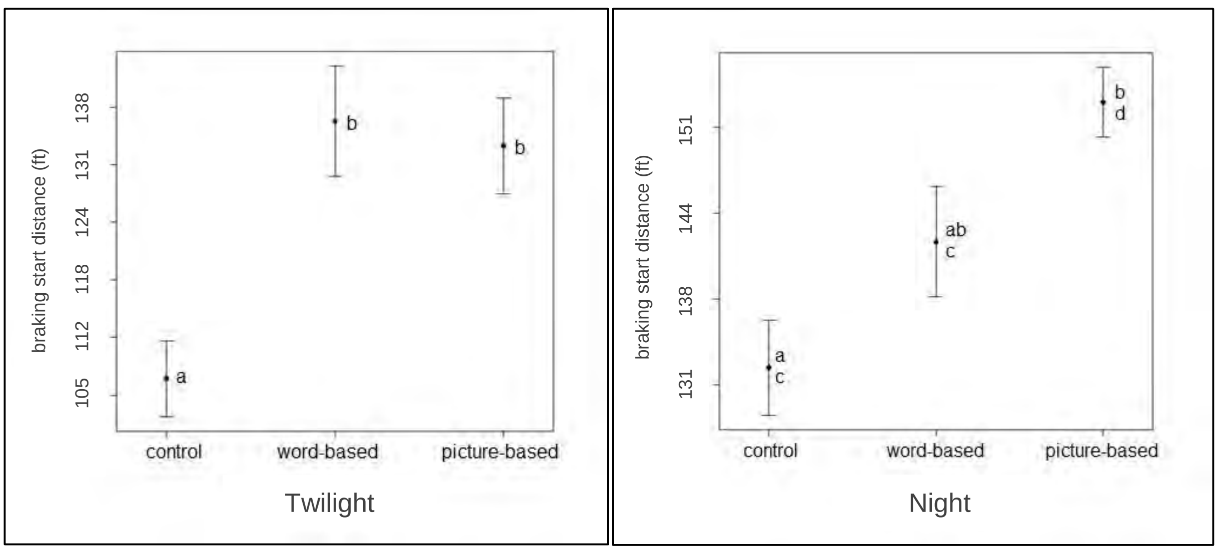

Figure 32. Braking Distance by Treatment. Significantly different treatments are denoted by letters (a and b indicate significant differences at α= 0.05; c and d indicate significant differences at α= 0.10). **Left-** the three treatments at twilight; control n=26, word- and picture-based n= 29 after removing outliers (>3 SD from the grand mean); **Right-** the three treatments at night; control n=27, word- and picture-based n=30. Nighttime data were transformed using the Box-Cox transformation, but values in this figure are untransformed.

At night, braking distance was influenced by treatment, but not age, although the interaction between treatment and age was significant at α = 0.10 (Table 18). Participants in the picture-based treatment started to brake on avg 18.1 ft before participants in the control treatment (significant difference; Tukey-Kramer HSD, p = 0.0006; Fig. 32) and 10 ft before participants in the word-based treatment (significant at α =0.1; Tukey-Kramer HSD, p = 0.0725; Fig. 32). Participants in the word-based treatment started to brake 8.2 ft before participants in the control treatment, but this difference was not significant (Tukey-Kramer HSD, p = 0.189).

Because the interaction between age and treatment at night was close to being significant at $\alpha = 0.05$, and because we tested a relatively small sample of participants, we investigated the interaction for any trends indicating that the different RADS designs affected participants differently within an age group. Within age group 1 (the youngest age group), those participating in the picture-based group braked on average 25.5 ft before those participating in the control group (Tukey-Kramer HSD, $p = 0.0749$). Within age group 3 (the oldest age group), those subjected to the picture based group braked on average 25.6 ft before those subjected to the word-based group (Tukey-Kramer HSD, $p = 0.0714$).

The trends within the interaction of RADS treatment and age group on braking start distance are worth further consideration. Drivers in both the youngest and oldest age groups started braking earlier in response to picture-based RADS signs. Because the animal entered the road at the same point for all participants, the distance at which participants started braking is a proxy for brake reaction time. Brake reaction time (BRT) is the amount of time that passes between the moment the stimulus appears and when the driver's foot actually reaches the pedal (Shinar 2007). Contained within BRT is perception reaction time (PRT), the amount of time passed between the point a stimulus reaches a driver and the driver initiates a response. The BRT is therefore affected by the PRT; if people are primed to expect a stimulus, their PRT (and therefore, BRT) should be reduced. The slower the PRT, the longer the stopping distance, increasing the chance of collision (Shinar 2007). Thus, it appears that for two of three age groups tested, the picture-based RADS signs did a better job of priming participants to expect an animal, and therefore may be more effective in preventing collisions.

We found significant differences in driver behavior at twilight and at night. Average speed was lower at night, which is almost certainly due to the different speed limits at twilight and night (60 mph vs. 45 mph, respectively) and reduced sight distance in lower light conditions. The reduction in speed was accompanied by earlier braking distances and a greatly reduced number of crashes at night. The lower nighttime speed limit in BCNP was put in place to reduce animal-vehicle collisions, especially collisions with Florida panthers, and the results of this simulation support the potential effectiveness of this measure.

Simulator validity – Behaviors observed in a driving simulator may not accurately reflect real-life behaviors. The validity of using driving simulators to predict real-world crash rate was reviewed by Rudin-Brown et al. (2009). Although simulators cannot perfectly recreate real-world driving conditions, they concluded that the use of a simulator is acceptable if it recreates conditions with enough validity to measure the behavior being investigated. Behavioral validity can be absolute—do the simulator observations exactly match those in the real world?—or relative—do simulator observations have the same direction and similar magnitude to those in the real world? (Blaauw 1982). If the goal of a simulator experiment is to measure the effect of one treatment vs. another, as is often the case in human factors research, ensuring that simulators have adequate relative validity is more important than ensuring absolute validity (Törnros 1998). In many studies evaluating driver speed, simulations achieved relative validity but not absolute validity (Törnros 1998; Klee et al. 1999; Godley et al. 2002; Bella 2008), though absolute validity has been documented (Yan et al. 2008). For this study, we compared speeds recorded during the simulation experiment to field recordings of speed through the US 41 RADS zone in BCNP. Simulator participants in the word-based RADS treatment drove 3 mph slower than those in the control treatment. Comparatively, US 41vehicles (in tourist season) in the RADS treatment drove 2.37 mph slower than those in the control treatment. This satisfies the guidelines described above by Blaauw (1982) for tests of relative validity.

F. Driver Response: Citizen Questionnaire

The purpose of the questionnaire was to obtain opinions from local residents, commuters and visitors regarding the impacts of roads on wildlife and their knowledge about RADS (including the system installed on US 41) designed to reduce wildlife-vehicle collisions and improve human safety. This information was used to assess the existing level of public knowledge about the function and purpose of RADS and its possible effect on the current effectiveness of RADS, and to establish the need for public education efforts to improve driver awareness.

Methods

A simple written questionnaire was produced and distributed at public places near the project area and in the Everglades City community. The majority of respondents were obtained at the main visitor's center at BCNP and H.P. Williams Park. Staff were stationed at tables in front of these locations and actively requested that visitors fill out the surveys. Following completion of the surveys, respondents were handed informational brochures produced by FDOT that explained the purpose and function of the RADS. These active survey periods occurred over two weekends, Jan 24-25 and Feb 13-14 of 2015. Staff actively polled respondents at the local grocery store in Everglades City on Apr 30th, 2014. A significant number of respondents were obtained by making questionnaires available at the counter in the Collier County Chamber of Commerce Visitor Center at the intersection of SR 29 and US 41 in May and Dec of 2014 and Jan of 2015. The questionnaire was also made available online, and was advertised in the May 23-Jun 5 2014 issue of the Everglades City local newspaper, The MulletRapper.

The questionnaire consisted of 10 single answer questions. Respondents were polled about:

- familiarity with the local area,
- level of knowledge on function and purpose of RADS,
- awareness of the US 41 RADS,
- how they obtained knowledge about RADS,
- where they may have previously seen or heard about RADS,
- why it is important to reduce wildlife-vehicle collisions,
- familiarity with the Florida panther, its status and impacts from roads

We also asked general questions on demographics including the respondent's place of residence, age, sex, and profession.

Information from the questionnaire was analyzed to determine public perception and acceptance of animal detection systems and other wildlife mitigation measures. We generated summary statistics and performed a one-tailed chi-squared test to evaluate significance of responses. We analyzed 192 completed individual questionnaires.

Results and Discussion

Demographics – Responses to general demographic questions are provided below. Most respondents were from other states (62%), while less than 10% were local and another 15% were from other cities in Florida. Less than 10% were international. Local and in-state residents made up 78.9% of responders in the off-season, yet they only made up 20.5% during tourist season. Some bias is likely inherent though due to our survey collection method. Nevertheless, tourist traffic dominates the area in winter. Age demographics show that most respondents fell within the 56-70 yr group (44%), then the 41-55 yr group (22%), then the 71-85 yr group (18%) and then 26-40 yr group (10%). Based on age, the majority of respondents likely had considerable driving experience. Sex ratio of respondents was skewed somewhat to males, 1.3:1. Regarding profession, only 3% were in a wildlife-related profession and 43% were retired.

Where do you live?	Number responses	Percent responses
Local (Ochopee, Chokoluskee, Everglades City, Naples)	17	8.9
In-state (other Florida city)	29	15.1
Other US state	119	62.0
Non-US	18	9.4
No response	9	4.7

Age	Number responses	Percent responses
18-25	4	2.1
26-40	19	9.9
41-55	43	22.4
56-70	84	43.8
71-85	34	17.7
86 +	1	0.5
No response	7	3.6

Sex	Number responses	Percent responses
Female	81	42.2
Male	106	55.2
No response	5	2.6

Wildlife-related profession*	Number responses	Percent responses
Yes	6	3.1
No	98	51.0
Retired	83	43.2
No response	5	2.6

*e.g., bird guide, Everglades chamber of commerce, forester, naturalist, swamp buggy guide

Individual survey questions – A summary of responses by question is provided below. Regarding local knowledge of the area, nearly 40% had never visited BCNP. Nearly even numbers of respondents had either visited BCNP before or after installation of RADS and 42 (22%) had driven through or visited in both periods (Question #1).

1. Have you ever visited or driven through Big Cypress National Preserve (BCNP) **before today**?

Response		Number responses	Percent responses
No		75	39.3
Yes, I have visited or driven through:	Before January 2012	29	15.2
	After January 2012	25	13.1
	During both of these periods	42	22.0
	Not sure of the date	16	8.4
No response		4	2.1

In polling respondents on knowledge of RADS, 131 (69%) were unfamiliar with it (Question #2). Question #3 was a follow-up to Question #2 for those that answered affirmatively that they did know what a RADS was. They were asked to describe what its function was. Interestingly, we received only 116 responses (60%) in Question #3 saying they didn't know what RADS was. This means that either some respondents misunderstood the question, or those that didn't know what RADS was (based on responses in Question #2) tried to guess its function. Just as many thought RADS were static warning signs as did those that correctly answered that RADS were flashing warning signs activated only when animals were present. Over 50% of respondents were not aware of the US 41 RADS in BCNP (Question #4). Of those that had seen the RADS on US 41, nearly 19% didn't know what it was (Question #5). Responses to question #6, reveal that 40% were unaware of the US 41 RADS, and of those that were found out by driving by (39%), from word of mouth (10%), or from a brochure (4%). In question #7, only 14% responded affirmatively that they were aware of RADS in other locations. Answers to question #s 2-6 indicate that little knowledge of RADS function or its presence on US 41 exists either in south Florida or from outside visitors.

2. Do you know what a Roadside Animal Detection System (RADS) is?

Response	Number responses	Percent responses
Yes	57	29.8
No	131	68.6
No response	3	1.6

3. If you know what a Roadside Animal Detection System (RADS) is, what is your understanding of its function? If your answer is not fully represented by the options below, please choose "Other" and write your answer. (If you do not know what a RADS is, proceed to the next question).

Response	Number responses	Percent responses
I don't know what a RADS is	116	60.4
a) It is a set of signs which warn drivers that animals are often seen crossing the road in this area.	30	15.6
b) When animals are on or near the road, flashing lights or signs warn drivers.	31	16.1
c) When animals are on or near the road, the system scares them away.	0	0.0
d) Other	5	2.6
e) a and b	9	4.7
f) a, b, and c	1	0.5

4. Are you aware that there is a Roadside Animal Detection System (RADS) operating along a section of U.S. Highway 41 in Big Cypress National Preserve?

Response	Number responses	Percent responses
Yes	89	46.4
No	98	51.0
No response	5	2.6

5. Have you seen the Roadside Animal Detection System (RADS) on U.S. Highway 41? (Picture on banner)

Response	Number responses	Percent responses
Yes	83	43.2
No	69	35.9
Yes, but I didn't know what it was at the time	36	18.8
No response	4	2.1

6. How did you learn about the Roadside Animal Detection System (RADS) on U.S. 41?

Response	Number responses	Percent responses
I was not aware that it existed	77	40.1
I saw it while driving on U.S. Highway 41 through Big Cypress	75	39.1
From an informational brochure/flyer/news article	8	4.2
Word of mouth, e.g., park employee, law enforcement officer, etc.	19	9.9
I received an email about it from a mailing list	0	0.0
Other	3	1.6
Driving and brochure	1	0.5
Driving and word of mouth	2	1.0
No response	6	3.1

"Other" responses:

your info center

from your survey

saw it, but didn't know what it was

7. Have you seen or heard about a roadside animal detection system that is/was installed elsewhere?

Response	Number responses	Percent responses
Yes	28	14.6
No	159	82.8
No response	5	2.6

"Other" responses

Alberta-Banff National Park (2 separate responses)

Canada (2 separate responses)

AR, GA

Florida - Ocala, bear signs (Hwy 27)

Indiana (2 separate responses)

Newfoundland

North Carolina (3 separate responses)

Ohio or Indiana, 5+ years ago

Oregon - Cazir

Utah

Utah - Grand Esplanade

VA

Wisconsin

Michigan, cons biology course at Mich Tech U

Lots of states for various animals

Elk out west

Question #s 8 – 10 referred to issues about animal vehicle collisions and Florida panthers. In response to question #8, survey takers indicated that human safety and protection of wildlife (105, 55%) were the most important reason to reduce rates of wildlife-vehicle collisions. The second most common response (53, 28%) was protection of wildlife only. Question #9 revealed that most people were aware that panthers were endangered (148, 77%), but some didn't know the population estimate was so low (40, 21%). At a rate of about 2:1, respondents in question #10 indicated they weren't aware that the annual number of panther deaths in vehicle collisions was so high.

8. In your opinion, what is the most important reason to reduce the rate of animal-vehicle collisions? (If two answers are equally important to you, you may select both.)

Response	Number responses	Percent responses
Human safety	12	6.3
Protection of wildlife	53	27.6
Property damage	1	0.5
Human safety and protection of wildlife	105	54.6
Human safety and property damage	1	.5
Protection of wildlife and property damage	8	4.2
Human safety, protection of wildlife and property damage	8	4.2
Other	0	0
No opinion	0	0
No response	4	2.1

9. Are you aware that one of the most symbolic animals of BCNP, the Florida panther, is highly endangered, with a population of only 100-160 individuals?

Response	Number responses	Percent responses
Yes	108	56.3
No	41	21.4
I knew that they were endangered, but I did not know that the population was so small.	40	20.9
No response	3	1.6

10. Are you aware that over the past 5 years, an average of 15 Florida panthers per year have been killed in collisions with automobiles?

Response	Number responses	Percent responses
Yes	68	35.4
No	121	63.0
No response	3	1.6

Statistical analysis – One-tailed chi-squared tests were performed on three questions we devised based on the citizen questionnaire data. For all tests, we excluded "don't know" or "no response," so total *n* varies from test to test. **First**, were people who had driven on US 41 previously (while the RADS was in place) more likely to report knowing *what* the RADS was (survey question #s 1 and 2)? The simple answer was yes (X^2= 18.1 on 3 d.f., n= 170, p < 0.001). People who had not driven on US 41 before the day of the survey were more likely to say that they did not know what the RADS was. **Second**, were people who reported that protecting wildlife was a high priority more likely to report knowing *what* the RADS was (survey question #8)? The only categories included were "humans," "wildlife," and "humans and wildlife" because all other categories had too few responses for chi-squared analysis. "Humans" and "humans and wildlife" were combined into one group because there were too few responses for the “humans” category independently. We used Yates correction because it was a 2x2 table. No evidence of this pattern was identified (X^2= 0.55 on 1 d.f., n= 163, $p > 0.5$). **Third**, were people who had driven on US 41 previously (while the RADS was in place) more likely to know *how* the RADS worked? For this we used Yates correction because some cells had <10 data points. For the analysis, responses were collapsed into correct (responded with only the correct answer), partially correct (chose correct answer and a wrong answer), and incorrect. Again, there was no evidence of this pattern (X^2= 1.61 on 2 d.f., n= 65, $p > 0.5$).

Results of this survey demonstrated that the public is generally unfamiliar with the RADS system, its purpose and how it functions. For RADS to be effective, public education is essential as the system relies heavily on driver response. Efforts to increase public understanding and driver awareness are needed.

Conclusions and Recommendations

The purpose of this study was to assess the reliability of the RADS in correctly detecting target wildlife species that enter the roadway and the effectiveness of the warning signage in reducing speed and increasing driver alertness. Two panthers were killed in vehicle collisions in the RADS zone in 2012 after the RADS system was activated. Few road-killed target species were observed during the field study: American alligator (14), white-tail deer (1) and river otter (1). However, from tracks and camera trap stations we documented that many successful crossings of US 41 by target species occurred at three primary locations, Trail Lakes land bridge, Turner River canoe launch and Turner River Road (see fig. 9). Tracks of target species observed included Florida panther (61), bobcat (131), Florida black bear (64), white-tail deer (82) and American alligator (2). On camera traps we captured photos of Florida panther (91), bobcat (239), Florida black bear (50), white-tail deer (927) and American alligator (6).

Importance of Land Bridges and Structures Bridging the Canal

Our results identified the three locations (Trail Lakes land bridge, Turner River canoe launch and Turner River Road) where the canal is "bridged " by either culverts or roads as the most critical crossing sites used by the target species. Deficiencies in the RADS sensor arrays exist at all three of these locations. At the Trail Lakes land bridge, there is a coverage gap on the south-side of the road allowing many target animals to travel from south to north undetected. The westernmost sensor section on the southside of the road needs to be extended approximately 300 ft west to cover the capture area of animals moving toward the landbridge on the northside. The sensors on the northside extend across the landbridge, but are too close to the pavement and do not allow for enough advance warning to drivers that are in close proximity to this location. Improved performance can be achieved by adding additional sensor poles and moving the infra-red beam further back near the far side of the land bridge (fig. 33). At Turner River canoe launch, the same approach to design is applicable, both at the swale/landbridge near the boat ramp (fig. 34) and at the driveway (fig. 35). The objective is to move the infra-red beam approximately 15 to 20 ft from US 41 pavement which will vastly improve response times of drivers when notified of animals approaching from the northside of the road. In the case of the driveway, it would also be necessary to relocate the magnetic loop along the same line as the sensor pole locations so that vehicles do not trigger the warning signs when they "break the beam". The current infra-red beam at the driveway aims over the guardrail; this may be too high to detect many of the target species which would explain some of the false negatives at this site. We recommend that the sensor boxes be moved down and holes cut in the guardrail so the beam could be lowered. Finally at Turner River Road, the sensor sections on the north and south sides of US 41 need to be extended to the bridge over the canal at H.P. Williams to encompass the animal crossing area adjacent to H.P. Williams Park and Turner River Road (fig. 36). We recorded multiple panther crossings here undetected because it is outside the RADS sensor zone. As with the previous described examples, setting the sensors back 15 to 20 ft on the northside is highly recommended. A magnetic loop would also need to be installed on Turner River Road to address intersecting vehicle traffic.

Animal Detection Performance

We compared date/time stamps of photographic data to sensor logs to tabulate successful detections, false negatives and false positives. Overall, the RADS performed from poor to fair in detecting target species; we recorded average success rates between 10.7% and 66%. We also found that on average, between 34% and 89.3% of target animals were not detected, resulting in false negatives. Over 90% of all RADS activations were classified as false positives (Table 5). The resulting effect is that the large number of false positives could be desensitizing drivers to the RADS. If the RADS is constantly flashing and animals are not present, they will eventually disregard the warning system. Table 7 displays the magnitude of triggers occurring on average per month. Over 75% of these occur during the day, when we've observed warning signs constantly flashing. These far exceed the number of animals we independently recorded for just 5 sections (Table 5 and 6). Several possibilities exist to explain the high level of false positives including physical obstructions, adverse environmental effects, and mechanical/electronic malfunction. The problem is likely multi-causal in nature. Making it a priority to troubleshoot the causes and rectify these is critical to the systems success and evaluation. We recommend a complete shutdown of the system and a major physical and electronic evaluation be completed, identifying the cause for the chronic false positives. Correcting these could vastly improve the function and effectiveness of the system.

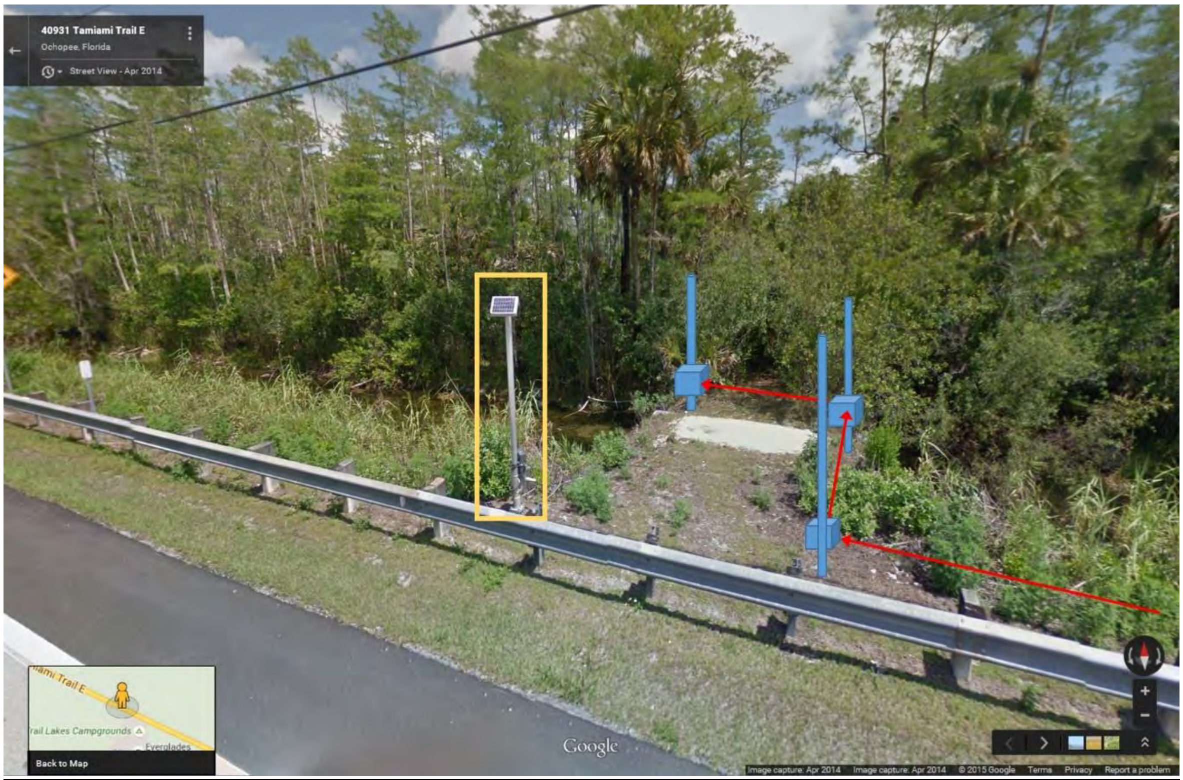

Figure 33. Illustration of Reconfiguration of Sensors at the Trail Lakes Land Bridge. Adding sensor poles further back near the far side of the land bridge translates into an earlier trigger of the RADS warning signs and more advance warning to drivers of impending conflicts with animals approaching the road. The existing sensor pole (highlighted by the orange rectangle) would be unnecessary and can be moved to one of the proposed locations.

Use of a control site to test the RADS did not provide measurably better detection success or reductions in false negatives, however it did result in reducing the number of false positives by nearly 50% below that of the US 41 system. Although it was easier to control for some constraints on US 41 such as vegetation growth or vehicles pulling off the road and triggering the sensor, we still encountered system malfunctions that negatively affected results.

Figure 34. Illustration of Reconfiguration of Sensors at the Turner River Canoe Launch. Adding sensor poles 15 to 20 ft further from US 41 translates into an earlier trigger of the RADS warning signs and more advance warning to drivers of impending conflicts with animals approaching the road.

Figure 35. Illustration of Reconfiguration of Sensors at the Turner River Canoe Launch Driveway. Adding sensor poles further back near the far side of the intersection translates into an earlier trigger of the RADS warning signs and more advance warning to drivers of impending conflicts with animals approaching the road.

Figure 36. Illustration of Extension of Sensor Section at Turner River Road. Extending the sensor section to the bridge east of H.P. Williams Park would incorporate a significant road crossing used by panthers and other target species. Adding sensor poles further back of the intersection and the adjacent guardrail translates into an earlier trigger of the RADS warning signs and more advance warning to drivers of impending conflicts with animals approaching the road from the northside.

Speed Surveys

To assess driver response to RADS, we measured the speed of individual cars on US 41 when the RADS was active (flashing) and inactive (not flashing). In the tourist season, the activation of the RADS caused a significant reduction in vehicle speed (2.37 mph). Using power functions to estimate the effect of reducing speed by 1 mph at 60 mph and 45 mph posted limits corresponded to a 3.1% and 4.2% decrease in crash rate, respectively (Aarts and van Schagen 2006). There was a significant interaction between season and time of day. During the tourist season, drivers drove faster (3.44 mph) at twilight than at night. The same effect was observed in the off-season, though the difference was not as large (1.96 mph). The overwhelming factor influencing speed was time of day. Despite the fact that drivers in the tourist season generally drove faster than those in the off-season, tourist-season drivers responded to the RADS by driving more slowly, while off-season drivers did not. We suggest that this result is from acclimation by local drivers to the RADS.

Driving Simulator

The driver simulation experiment produced many significant and positive results useful in improving RADS effectiveness. Participants in RADS treatments exhibited:

1) more significant reductions in speed,
2) earlier braking response to an animal in the road,
3) fewer collisions with animals,

4) greater reductions in speed at twilight when exposed to picture-based rather than word-based RADS signs, and
5) an increase in reaction time (braking distance) at night when exposed to picture-based rather than word-based RADS signs.

These results lend empirical support to survey results that drivers rate picture-based signs higher for increasing alertness (Bond and Jones 2013). Although less crashes occurred in picture-based treatment than in word-based treatment, this difference was not significant. However, this could be the result of a relatively low sample of crashes in our study; with more participants, we suspect that these trends would become significant.

Citizen Surveys

Results of the citizen survey indicate that public familiarity with the RADS system, its purpose and how it functions is deficient. We recommend a concerted effort to educate the local community about it through brochures, web pages, public service announcements, postings at visitor centers and kiosks, and by disseminating information through local chamber of commerce and business bureaus in communities linked by US 41 and SR 29, in particular Naples, Ft. Myers and Miami-Dade.

Signage

Adequate notification of animal presence, or lack thereof, by clearly visible signs was another issue identified in the study. First, clutter, sensory overload and obstructed view from too many signs in very close proximity appears to be a significant problem at many of the locations where RADS warning signs were placed (fig. 37). The warning sign most obstructed from view is the second eastbound sign (fig. 38). Second, we identified two very significant gaps in the sensor zone where drivers are not warned by the current number and placement of RADS warning signs. Specifically we are referring to the eastbound and westbound terminus of the sensor zone. These locations feature land bridges (Trail Lakes, Turner River Road) over the northbound canal adjacent to US 41 that exhibit high levels of animal crossing activity, including by panthers. In addition, the gap at the westbound terminus is near the location where the motorcycle-panther collision occurred in 2012. The driver was not informed of the panther's presence because he had already passed the last warning sign before the panther tripped the sensors.

To increase visibility and cover these significant gaps, we recommend that the number of lighted warning signs be increased to 4 in each traffic direction. The placement of the current 1st warning signs is adequate, subsequent warning signs should be spaced apart by approximately 1,755 ft with the final sign in each direction beyond the last sensor pole. Care should be taken with the exact placement to minimize obstruction by other road signs. The need for many of the signs should be reviewed, and likely some could be removed. For instance, many of the old wildlife warning signs and panther crossing signs can still be found within the RADS sensor zone. Given that this is a specialized crossing zone and the lighted warning signs have been added, these could probably be removed to reduce clutter.

Alternative Designs

Roadside animal detection systems are a promising technology in reducing the frequency of animal-vehicle collisions, but empirical testing on US 41 has demonstrated chronic system malfunctions. Findings of the simulator experiment suggest that RADS can indeed produce the intended results on reducing crash probability, driver speed, and latency to brake. We identified several site design flaws with this system, some of which were discussed above (e.g, signs and sensor pole placement at important crossing sites). The site design and installation is a crucial step in maximizing the effectiveness of the system and minimizing maintenance and system down-time. We offer the following optional recommendations to improve system reliability and effectiveness:

1. **Retain current system with minimal modifications –**

   Given that this option would continue the operation of the entire sensor length, it is absolutely crucial to shut down the system, identify the cause(s) of false positives and correct the problems. The current coverage and number of sensors increases the complexity of the system and makes it difficult to monitor and maintain optimal performance. Reestablishing the wireless monitoring connection is also a must to improve maintenance response times to system faults and malfunctions. As part of this option we highly recommend implementation of the modifications discussed in the above section entitled, "Importance of Land Bridges and Structures Bridging the Canal".

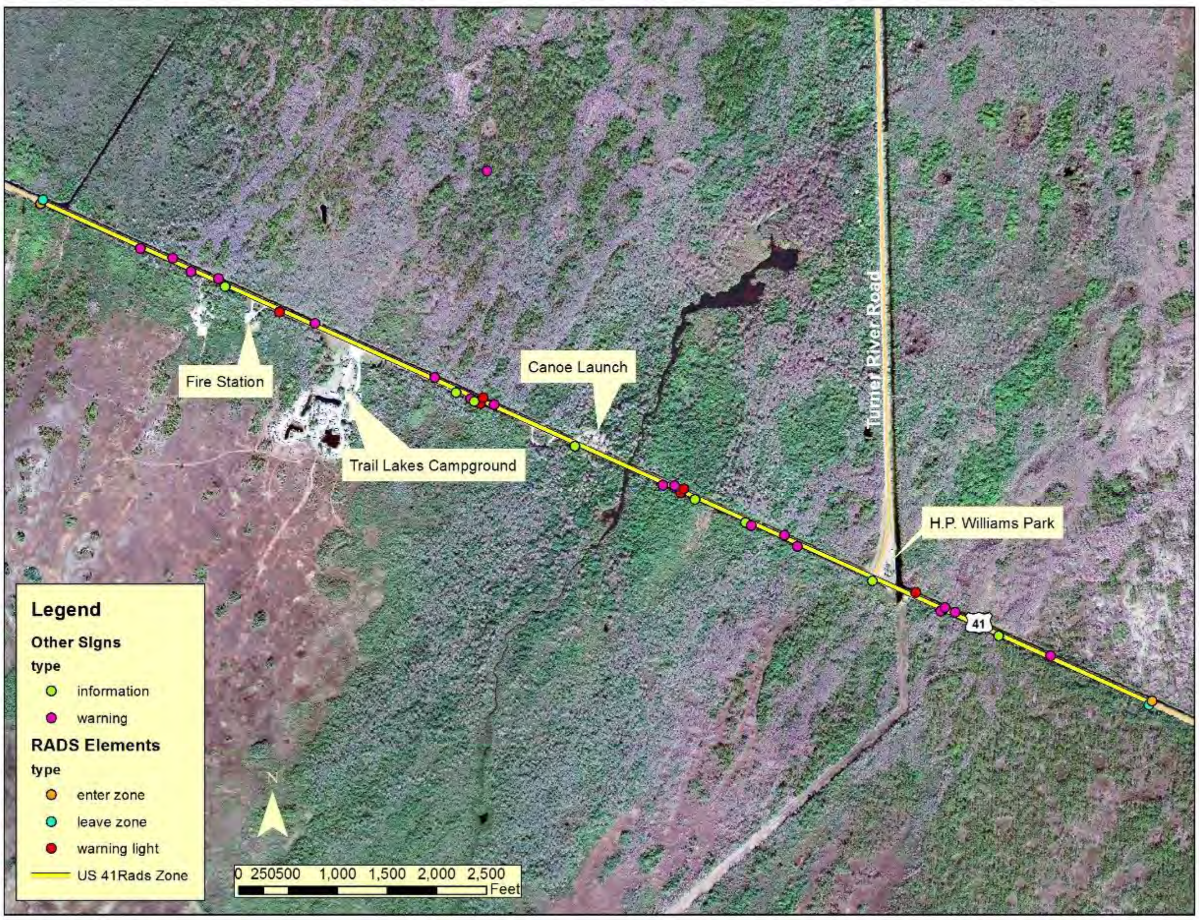

Figure 37. Map Showing Locations of All Signs within the RADS Sensor Zone. Note: RADS flashing warning signs are shown in red amongst a cluster of other signs. View of all westbound RADS warning signs are partially obstructed by other signs and/or vegetation; the last two eastbound RADS warning signs are also partially obstructed.

Figure 38. Obstructed View of Second Eastbound RADS Lighted Warning Sign. Left: More distant view showing that the warning sign is near completely obscured by multiple warning and information signs (see red arrow). **Right:** Closer view showing warning sign now exposed, but still partially hidden behind an information sign facing the other traffic direction.

2. **Retain current system, but limit operation to time of day when target animals most active –**

   This option would discount the incessant daytime false triggers (this is in the order of many 1000s of triggers per month on average system-wide, approximately 75% of which occur during the day). Essentially it would run from twilight hours to after dawn hours when the majority of target species are most active and crossings are likely to occur. The downside of this option is that animal movement isn't exclusive to nighttime hours, so some crossings, though it may be few, will occur during daytime hours while the system was not operational. System shut down and complete evaluation/repair and the modifications recommended in option 1 also apply here.

3. **Reduce current system to three smaller coverage areas at critical crossing locations –**

   In this alternative, we recommend simplifying the system to cover those locations where the most crossing activity has been observed and recorded. Specifically we are referring to Trail Lakes land bridge, Turner River canoe launch and Turner River Road. Characteristics and importance of these locations are discussed throughout this report and recommended site designs are presented in the above section entitled, "Importance of Land Bridges and Structures Bridging the Canal". Reducing the sensor coverage to these short sections would reduce the number of potential malfunctions and be easier to monitor and maintain.

4. **Remove and replace the above ground "break the beam" animal detection system with technology more suited to the US 41/Turner River location –**

   This last option involves abandoning efforts to restore the current system at this location. From our results, it is apparent that it is fraught with problems, partially due to the unsuitable nature of this location for this type of RADS. Rapid vegetation growth, a narrow right-of-way (with the limitation of the canal and guardrail immediately adjacent to the northside of the road), multiple driveways (two of which exhibit substantial traffic), and seasonally popular recreation sites (that attract many people) are opposite characteristics for what is needed for this above ground system to perform optimally with minimal maintenance. It is disappointing that potentially superior new designs were developed or in testing no more than a year or two after the decision was made to select this system for US 41.

   One potentially more suitable system for this location is a buried cable RADS. Excerpts below from Druta and Alden (2015) describe such as a system and its reliability, tested in Virginia:

   > The system, which consists of a "…buried dual-cable sensor, detects the crossing of large and medium-sized animals and provides data on their location along the length of the cable. The system has a central processor unit for control and communication and generates an invisible electromagnetic detection field around buried cables. When the detection field is perturbed, an alarm is declared and the location of the intrusion is determined. Target animals are detected based on their conductivity, size, and movement, with multiple simultaneous intrusions being detected during a crossing event. …Data analyses indicate that the ADS, if properly installed and calibrated, is capable of detecting animals such as deer and bear, and possibly smaller animals, such as fox and coyotes, with over 95% reliability. The ADS also performed well even when covered by 3 ft of snow. Moreover, the system was tested under various traffic conditions and no vehicle interferences were noted during the same monitoring period. The acquired data can be used to improve highway safety through driver warning systems installed along roadway sections where high wildlife activity has been observed. Additionally, this system may be integrated with the connected vehicle framework to provide advance, in-vehicle warnings to motorists approaching locations where animals have been detected in or near the roadway."

   Another similar buried cable system (OmniTrax from Senstar) has been tested in Colorado (Gray 2009). The buried cable systems would not be subject to problems associated with right-of-way vegetation maintenance, vehicles pulling on/off the road, traffic from intersecting roads, and presence of people (can be programmed not to trigger the system). This option is worth exploring in more depth.

   Another possible alternative is an animal detection system that uses Radar technology. This new system design is currently being tested (Tim Hazlehurst, Crosstek LLC, pers. comm.).

Other measures that would result in potentially significant improvement in system reliability/detection success and effectiveness:

- Make it standard protocol for maintenance crews to use the "mowing cycle" shutoff switch when performing any maintenance within the RADS sensor zone. Our observations were that most crews either didn't have access to the switch or simply didn't want to bother with it. Maintenance can last for hours setting the system off continuously and unnecessarily which contributes to drivers losing confidence in the system's accuracy.

- Offset all southside sensor poles another 5 to 10 ft from the pavement. The FDOT has significantly more right-of-way to the south of the road. The choice to place the current sensor poles within 10 ft of the pavement has resulted in many false positives as a result of vehicles pulling off the road and during periods of right-of-way maintenance. Again this contributes to drivers losing confidence in the system's accuracy.
- Remove and replace word-based warning signs with picture-based warning signs. Our study results have reinforced findings by other researchers that showed marked improvement in performance and recognition of picture-based signs in alerting drivers and achieving a positive response (reducing speed) to animal presence.
- Change the length of time that warning lights flash after being triggered. Currently they are set to flash for 5 minutes. We consider this time period too long and substantially exceeds the time it takes for animals to cross the road and for cars to pass through the RADS sensor zone. At 45 mph, it takes a car about 1 min 45 sec to drive through the 1.3 mi length RADs sensor zone. At 40 and 35 mph, this increases to about 2 min and 2 min 15 sec, respectively. Our speed surveys rarely recorded anyone driving through the zone below 35 mph. Given these speeds and driving times and that the average recorded duration for a FL panther or black bear to cross the road once it enters the cleared right-of-way was less than 30 sec, the time that warning lights flash after being triggered should be reduced to 2.5 min.

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APPENDIX A

Background Species Data

Appendix A-1. **Species Checklist.** Notes: This list includes all species that were identified during the course of field work in the project area; Visual observations listed only include target species, e.g., Florida panther, black bear, bobcat, coyote, white-tail deer and American alligator; Visual observations of non-target species were not recorded.

Common Name	Scientific Name	Roadkill	Tracks	Camera	Visual
Mammals					
Florida panther	*Puma concolor coryi*		X	X	X
Florida black bear	*Ursus americanus floridanus*		X	X	
Bobcat	*Lynx rufus*		X	X	
White-tailed deer	*Odocoileus virginianus*	X	X	X	
Coyote	*Canis latrans*		X	X	
Raccoon	*Procyon lotor*	X	X	X	
Virginia opossum	*Didelphis virginiana*	X	X	X	
domestic dog	*Canis familiaris*		X	X	
domestic cat	*Felis catus*		X	X	
Marsh rabbit	*Sylvilagus palustris*	X	X	X	
River otter	*Lutra canadensis*	X			
Crocodilians					
American alligator	*Alligator mississipiensis*	X	X	X	X
Snakes					
Common garter snake	*Thamnophis s. sirtalis*	X			
Pigmy rattlesnake	*Sistrurus miliarius barbouri*	X			
Eastern ribbon snake	*Thamnophis sauritus sackenii*	X			
Florida banded water snake	*Nerodia fasciata pictiventris*	X			
Ringneck snake	*Diadophis p. punctatus*	X			
Corn snake	*Elaphe g. guttata*	X			
Yellow ratsnake	*Elaphe obsoleta quadrivittata*	X			
Scarlet snake	*Cemophora c. coccinea*	X			
Southern black racer	*Coluber constrictor paludicola*	X			
Eastern diamondback	*Crotalus adamanteus*	X			
Florida cottonmouth	*Agkistrodon piscivorus conanti*	X			
Frogs					
Southern leopard frog	*Rana utricularia sphenocephala*	X			
Pig frog	*Rana grylio*	X	X		
Cuban treefrog	*Osteopilus septentrionalis*	X			
Squirrel treefrog	*Hyla squirella*	X			
Green treefrog	*Hyla cinerea*	X			
Southern toad	*Bufo terrestris*	X			

Appendix A-1. (cont'd)

Common Name	Scientific Name	Roadkill	Tracks	Camera	Visual
Lizards					
Green anole	*Anolis carolinensis*	X			
Turtles					
Florida red-bellied cooter	*Pseudemys nelsoni*	X			
Eastern mud turtle	*Kinosternon subrubrum steindachneri*	X			
Florida softshell turtle	*Apalone ferox*	X		X	
Birds					
Eastern screech owl	*Otus asio*	X			
Blue-gray gnatcatcher	*Polioptila caerulea*	X			
Great crested flycatcher	*Myiarchus crinitus*	X			
Common yellowthroat	*Geothlypis trichas*	X			
Gray catbird	*Dumetella carolinensis*	X			
Green heron	*Butorides virescens*	X			
Turkey vulture	*Cathartes aura*			X	
Great egret	*Ardea alba*			X	
White Ibis	*Bubulcus ibis*			X	
Peacock	*Pavo Cristatus*			X	
Great blue heron	*Ardea herodias*	X	X	X	
Black vulture	*Coragyps atratus*	X	X	X	
American crow	*Corvus brachyrhynchos*	X	X	X	
Anhinga	*Anhinga ahinga*	X			
Wild turkey	*Meleagris gallopavo*			X	

Appendix A-2. **Small Animal Road-kill Analysis**

All road-kill were recorded from Jan 2013 to Apr 2015. Smaller road-killed animals represent potential prey items of larger target species and influence their movements and behavior. The below reported data and analysis only indicates the potential effect of smaller road-kill species on larger species that would trip RADS sensors while scavenging along the roadside for prey items. This was not intended to obtain an accurate estimate of the total number of smaller species killed within the RADS zone. A more involved effort beyond our scope would be required to do this because of the high level of scavenging observed at this site.

Table A-2.1 displays the number of Non-RADS species of road-kills recorded. Frogs were by far the taxonomic group most observed as road-kill, though we think this estimate is low because of the level of scavenging that was observed, mostly by birds.

Table A-2.1. Non-RADS Road-kills Recorded from January 2013 to April 2015.

Species	#	%
other birds	41	2.81%
frogs	1269	87.04%
lizards	4	0.27%
snakes	86	5.90%
turtles	19	1.30%
small mammals	2	0.14%
meso-mammals	35	2.40%
bats	2	0.14%
total	1458	

Seasonal patterns of road-kills is shown in fig. A-2.1. Frogs demonstrated a sharp peak in May and a more gradual increase from September to November. One notable peak of reptiles occurred in November and more diminished peaks in four other months throughout the year. Road-kill of mammals and birds appeared to occur fairly even across the seasons.

The study area was divided into 25 m (82 ft) segments to record and display spatial patterns of road-kills. Figures A-2.2 and A-2.3 show locations of frog and snake road-kills, respectively. There were two notable patterns in these figs.: 1) two significant hotspots of frog road-kills occur about 1,000 ft east of the Turner River and just west of Turner River Road, and 2) two peak road-kill locations for snakes occurred just west of Trail Lakes Campground and approximately 1,500 ft west of Turner River. Too few turtle, bird and small- to meso-sized mammal road-kills were observed to reveal any significant spatial variance.

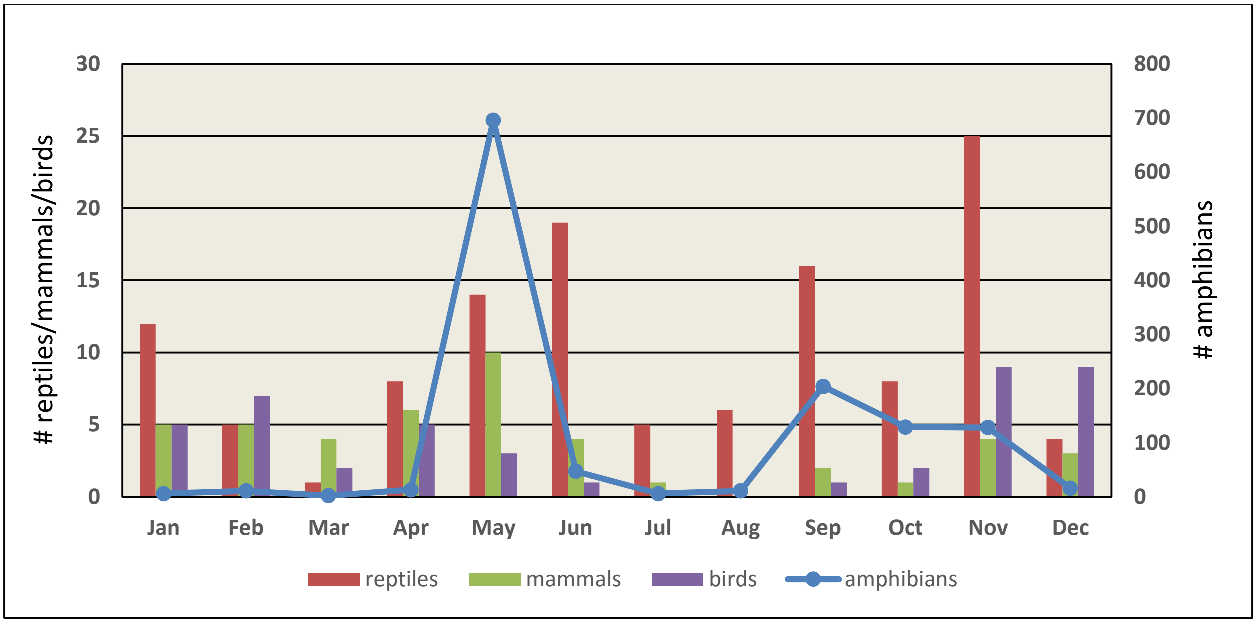


Figure A-2.1. Road-kills by Taxa by Month from Jan 2013 to Apr 2015.

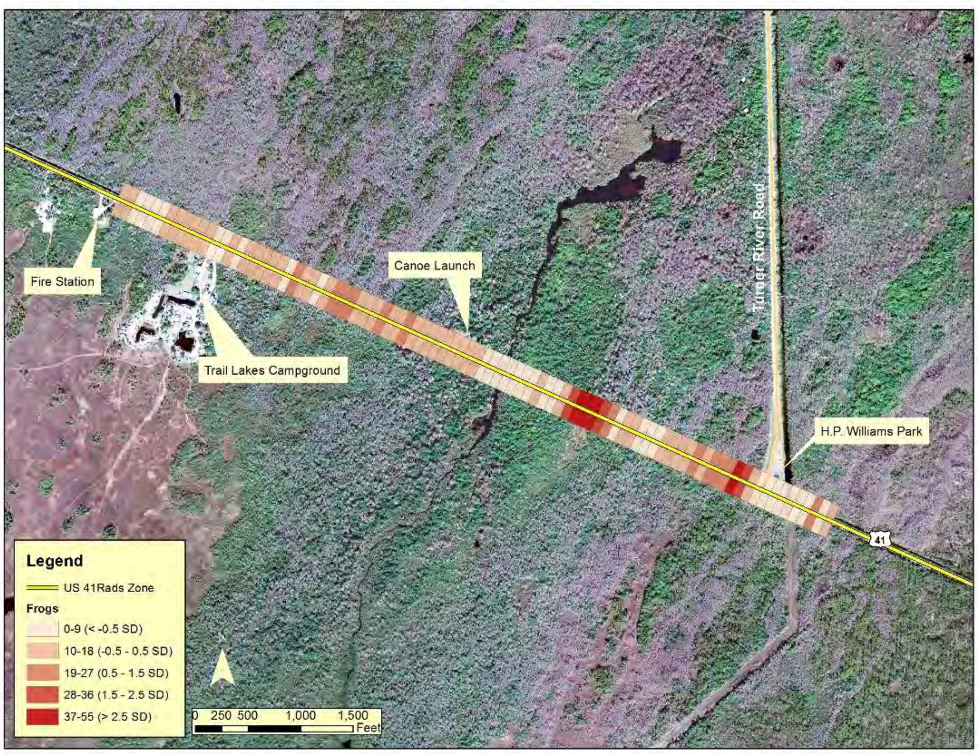


Figure A-2.2. Location of Frog Road-kills, Jan 2013 to Feb 2015. Note: road segments displayed equal 25 m (82 ft) in road length.

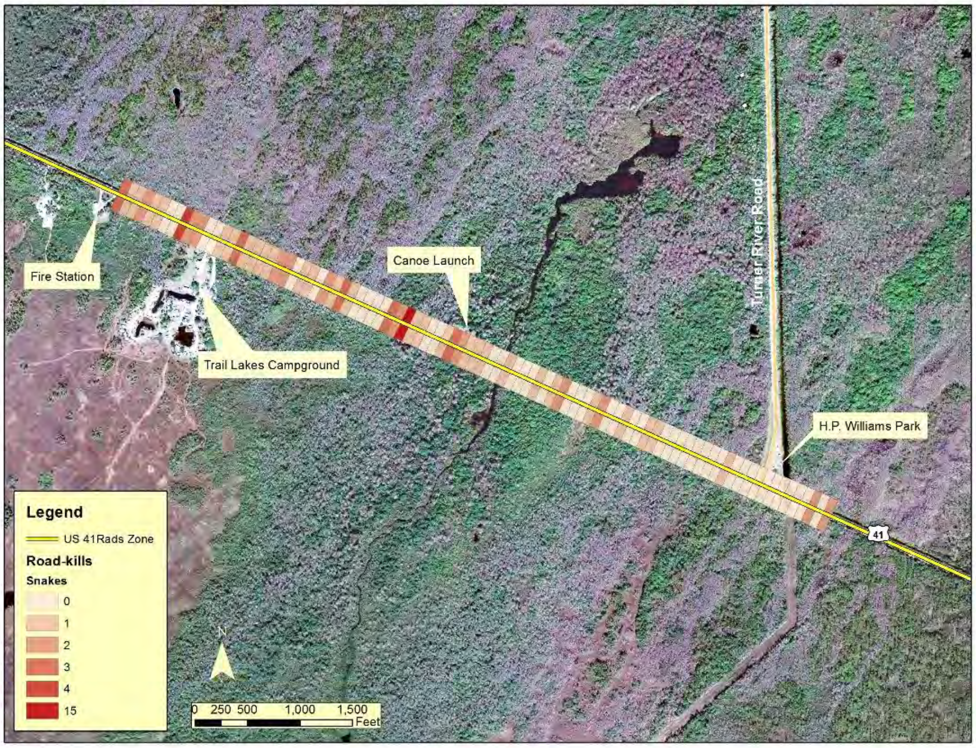
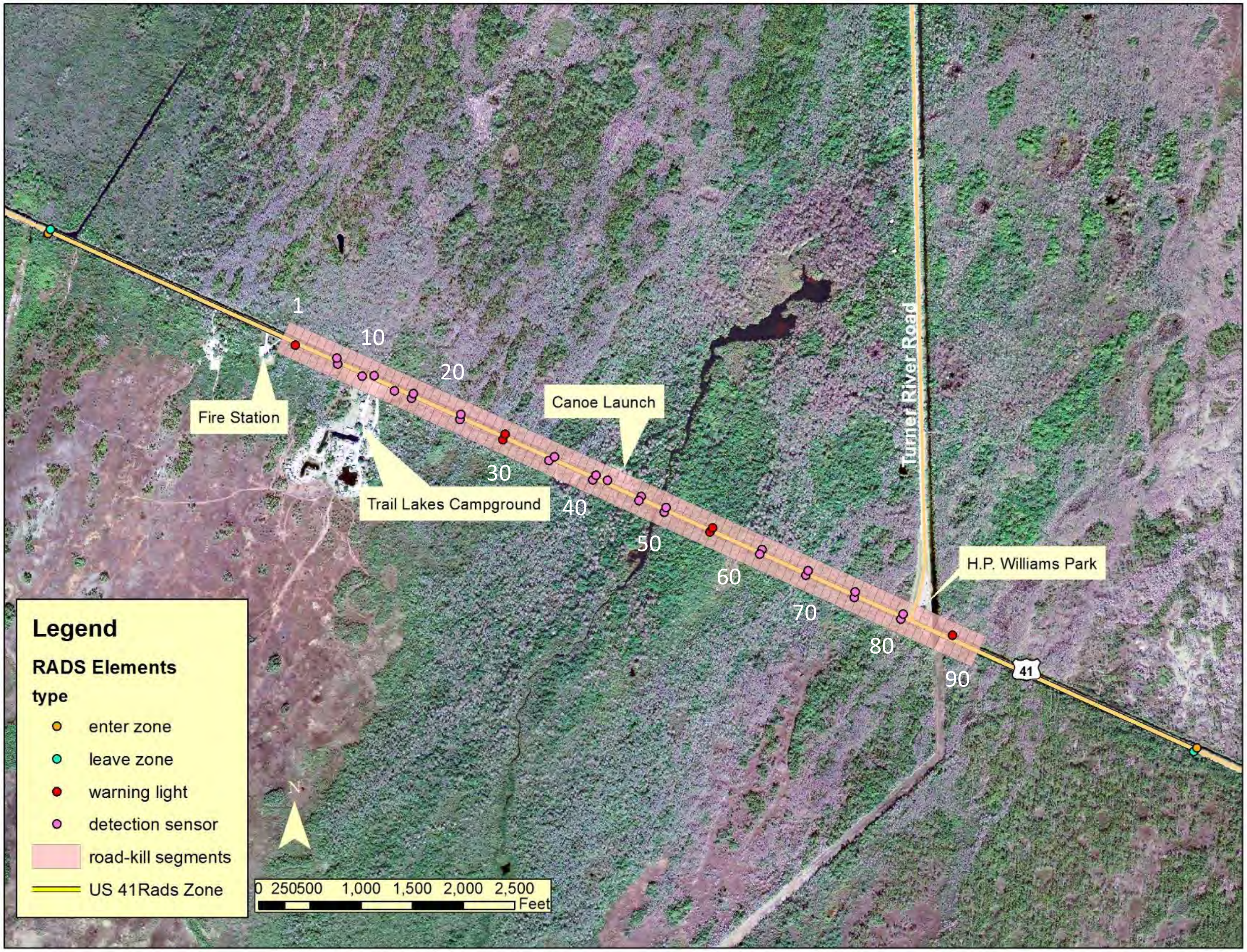


Figure A-2.3. Location of Snake Road-kills, Jan 2013 to Feb 2015. Note: road segments displayed equal 25 m (82 ft) in road length.

Appendix A-3. Road-kill Records in the Study Area (2013 – 2015). Below is a key to segment ID positions that correspond to the ensuing table.



Appendix A-3. Road-kill Records for the Study Area (2013 – 2015).

Date	Month	Mode	Segment ID	Lane	Location	Species	Number	Sex	Age Class
RADS (target species)									
4/29/2014	4	w	45	EB	on_road	Alligator mississippiensis	1	IN	J
4/17/2015	4	d	42	WB	shoulder	Alligator mississippiensis	1	IN	A
5/15/2014	5	w	59	WB	on_road	Alligator mississippiensis	3	IN	J
5/15/2014	5	w	60	WB	on_road	Alligator mississippiensis	2	IN	J
5/26/2014	5	d	60	EB	on_road	Alligator mississippiensis	2	IN	J
6/18/2013	6	d	91	EB	bike lane	Alligator mississippiensis	1	IN	J
6/18/2014	6	d	60	WB		Alligator mississippiensis	1	IN	A
7/19/2013	7	w	50	EB	shoulder	Alligator mississippiensis	1	IN	A
7/15/2014	7	d	81	WB		Alligator mississippiensis	1	IN	A
8/10/2013	8	d	39	EB	shoulder	Alligator mississippiensis	1	IN	A
12/5/2014	12	d	6	EB		Ardea alba	1	IN	A
1/25/2013	1	w	47	WB	shoulder	Ardea herodias	1	IN	A
2/5/2013	2	w	59	EB	shoulder	Ardea herodias	1	IN	A
11/22/2013	11	w	8	EB	on_road	Ardea herodias	1	IN	A
11/22/2013	11	w	88	EB	shoulder	Ardea herodias	1	IN	A
7/6/2013	7	d	63	WB	bike lane	Lutra canadensis	1	M	A
5/3/2013	5	w	43	EB	shoulder	Odocoileus virginianus	1	IN	J
Non-RADS (non-target species)									
1/25/2013	1	w	38	WB	shoulder	Agkistrodon piscivorus conanti	1	IN	A
1/29/2013	1	w	4	WB	on_road	Agkistrodon piscivorus conanti	1	IN	J
4/19/2013	4	w	5	EB	on_road	Agkistrodon piscivorus conanti	1	IN	J
7/22/2013	7	d	35	WB	shoulder	Agkistrodon piscivorus conanti	1	IN	A
10/18/2013	10	w	62	WB	on_road	Agkistrodon piscivorus conanti	1	IN	J
10/18/2013	10	w	91	WB	on_road	Agkistrodon piscivorus conanti	1	IN	A
10/22/2013	10	w	28	WB	on_road	Agkistrodon piscivorus conanti	1	IN	A
10/25/2013	10	w	6	WB	shoulder	Agkistrodon piscivorus conanti	1	IN	A

Appendix A-3. (cont'd)

Date	Month	Mode	ID	Lane	Location	Species	Number	Sex	Age Class
12/2/2013	12	w	1	EB	shoulder	Anhinga anhinga	1	IN	A
3/15/2013	3	w	61	EB	on_road	Anolis carolinensis	1	IN	A
4/17/2014	4	w	90	EB	on_road	Anolis spp.	1	IN	A
10/18/2013	10	w	63	EB	on_road	Anolis spp.	1	IN	A
12/5/2013	12	w	36	WB	bike lane	Anolis spp.	1	IN	A
2/7/2014	2	w	88	WB	shoulder	Apalone ferox	1	IN	A
7/9/2013	7	w	50	EB	bike lane	Apalone ferox	1	IN	A
1/25/2013	1	w	6	WB	shoulder	Aves	1	IN	IN
1/25/2013	1	w	34	WB	on_road	Aves	1	IN	IN
2/22/2013	2	w	59	WB	on_road	Aves	1	IN	IN
5/15/2014	5	w	47	WB	bike lane	Aves	1	IN	A
6/12/2013	6	w	64	EB	on_road	Aves	1	IN	IN
9/30/2013	9	w	44	WB	on_road	Aves	1		
10/22/2013	10	w	91	EB	on_road	Aves	1	IN	IN
11/15/2013	11	w	1	EB	shoulder	Aves	1	IN	A
11/15/2013	11	w	21	EB	on_road	Aves	1	IN	A
11/15/2013	11	w	90	WB	on_road	Aves	1	IN	A
11/18/2013	11	w	90	WB	on_road	Aves	1	IN	IN
12/2/2013	12	w	38	EB	on_road	Aves	1	IN	A
12/10/2013	12	w	62	EB	shoulder	Butorides virescens	1	IN	A
11/7/2014	11	d	87	WB	on_road	Cathartes aura	1	IN	A
5/6/2014	5	w	43	WB	on_road	Cemophora c. coccinea	1	IN	A
11/15/2013	11	w	79	WB	bike lane	Chiroptera	1	IN	A
12/2/2013	12	w	37	EB	bike lane	Chiroptera	1	IN	A
6/4/2013	6	w	89	WB	on_road	Coluber constrictor paludicola	1	IN	J
6/15/2013	6	w	29	EB	on_road	Coluber constrictor paludicola	1	IN	A
7/19/2013	7	w	25	EB	bike lane	Coluber constrictor paludicola	1	IN	A

Appendix A-3. (cont'd)

Date	Month	Mode	ID	Lane	Location	Species	Number	Sex	Age Class
8/7/2013	8	w	65	EB	shoulder	Coluber constrictor paludicola	1	IN	A
8/10/2013	8	d	29	WB	on_road	Coluber constrictor paludicola	1	IN	A
9/12/2013	9	w	50	WB	on_road	Coluber constrictor paludicola	1		
9/16/2013	9	w	69		on_road	Coluber constrictor paludicola	1		
9/26/2013	9	w	54	WB	shoulder	Coluber constrictor paludicola	1		
11/5/2013	11	w	16	WB	shoulder	Coluber constrictor paludicola	1	IN	A
11/18/2013	11	w	56	WB	on_road	Coluber constrictor paludicola	1	IN	A
1/18/2014	1	w	51	WB	bike lane	Coragyps atratus	1	IN	A
1/18/2014	1	w	54	EB	shoulder	Coragyps atratus	1	IN	A
1/30/2015	1	d	46	WB		Coragyps atratus	1	IN	A
4/29/2014	4	w	44	EB	shoulder	Coragyps atratus	1	IN	A
5/6/2014	5	w	47	WB	shoulder	Coragyps atratus	1	IN	A
10/25/2013	10	w	1	EB	shoulder	Coragyps atratus	1	IN	A
12/2/2013	12	w	39	EB	shoulder	Corvus brachyrhynchos	1	IN	A
9/26/2013	9	w	61	WB	on_road	Crotalus adamanteus	1		
2/21/2014	2	w	36	WB	bike lane	Diadophis p. punctatus	1	IN	J
1/18/2014	1	w	80	WB	shoulder	Didelphis virginiana	1	IN	IN
1/5/2015	1	d	69	WB	on_road	Didelphis virginiana	1	IN	A
2/21/2014	2	w	83	EB	shoulder	Didelphis virginiana	1	IN	A
3/12/2013	3	w	68	EB	shoulder	Didelphis virginiana	1	IN	A
3/26/2013	3	w	83	EB	shoulder	Didelphis virginiana	1	IN	A
4/2/2013	4	w	41	EB	shoulder	Didelphis virginiana	1	IN	A
4/6/2013	4	w	75	EB	shoulder	Didelphis virginiana	1	IN	A
4/16/2013	4	w	89	EB	shoulder	Didelphis virginiana	1	IN	IN
4/14/2014	4	w	39	EB	shoulder	Didelphis virginiana	1	IN	A
5/2/2014	5	w	41	WB	on_road	Didelphis virginiana	1	IN	A
5/23/2014	5	d	19	WB	shoulder	Didelphis virginiana	1	IN	A

Appendix A-3. (cont'd)

Date	Month	Mode	ID	Lane	Location	Species	Number	Sex	Age Class
5/23/2014	5	d	79	EB	shoulder	Didelphis virginiana	1	IN	A
6/10/2014	6	d	44	WB	on_road	Didelphis virginiana	1	IN	A
9/24/2014	9	d	44	EB	on_road	Didelphis virginiana	1	F	A
9/29/2014	9	d	21	EB	on_road	Didelphis virginiana	1	IN	A
10/22/2014	10	d	78	WB	on_road	Didelphis virginiana	1	IN	A
11/24/2014	11	d	?	WB	on_road	Didelphis virginiana	1	IN	A
12/15/2014	12	d	80	EB	on_road	Didelphis virginiana	1	IN	A
1/24/2014	1	w	8	WB	shoulder	Dumetella carolinensis	1	IN	A
2/19/2013	2	w	19	WB		Dumetella carolinensis	1	IN	A
2/22/2013	2	w	39	EB	on_road	Dumetella carolinensis	1	IN	A
2/28/2013	2	w	20	EB	shoulder	Dumetella carolinensis	1	IN	A
2/17/2014	2	w	42	EB	shoulder	Dumetella carolinensis	1	IN	A
2/28/2014	2	w	46	EB	shoulder	Dumetella carolinensis	1	IN	A
3/24/2014	3	w	6	EB	shoulder	Dumetella carolinensis	1	IN	A
3/31/2014	3	w	60	WB	on_road	Dumetella carolinensis	1	IN	A
4/2/2013	4	w	69	EB	shoulder	Dumetella carolinensis	1	IN	A
4/9/2013	4	d	52	EB	on_road	Dumetella carolinensis	1	IN	A
4/19/2013	4	w	63	WB	shoulder	Dumetella carolinensis	1	IN	A
1/25/2013	1	w	27	WB	shoulder	Elaphe g. guttata	1	IN	J
1/3/2014	1	w	57	EB	on_road	Elaphe g. guttata	1	IN	A
1/30/2014	1	d	39	WB	bike lane	Elaphe g. guttata	1	IN	IN
4/29/2014	4	w	57	WB	bike lane	Elaphe g. guttata	1	IN	A
5/10/2013	5	w	1	WB	on_road	Elaphe g. guttata	1	IN	A
5/9/2014	5	w	43	WB	on_road	Elaphe g. guttata	1	IN	J
9/12/2013	9	w	9	WB	on_road	Elaphe g. guttata	1		
11/1/2013	11	w	36	EB	on_road	Elaphe g. guttata	1	IN	J
12/10/2013	12	w	42	WB	bike lane	Elaphe g. guttata	1	IN	A

Appendix A-3. (cont'd)

Date	Month	Mode	ID	Lane	Location	Species	Number	Sex	Age Class
4/23/2013	4	d	47	WB	on_road	Elaphe obsoleta quadrivittata	1	IN	A
4/26/2013	4	w	62	WB	shoulder	Elaphe obsoleta quadrivittata	1	IN	J
11/15/2013	11	w	25	WB	shoulder	Geothlypis trichas	1	F	A
12/2/2013	12	w	49	WB	bike lane	Geothlypis trichas	1	IN	IN
12/10/2013	12	w	88	WB	shoulder	Geothlypis trichas	1	IN	IN
1/6/2014	1	w	11	WB	on_road	Kinosternon subrubrum steindachneri	1	IN	A
2/14/2014	2	w	15	EB	on_road	Kinosternon subrubrum steindachneri	1	IN	A
8/16/2013	8	w	29	EB	shoulder	Kinosternon subrubrum steindachneri	1	IN	A
2/24/2014	2	w	45	WB	shoulder	Mammalia	1	IN	A
4/16/2013	4	w	11	WB	on_road	Mammalia	1	IN	IN
5/3/2013	5	w	8	WB	on_road	Mammalia	1	IN	IN
6/12/2013	6	w	34	WB	on_road	Mammalia	1	IN	IN
4/16/2013	4	w	27	EB	bike lane	Myiarchus crinitus	1	IN	A
1/6/2014	1	w	91	EB	on_road	Nerodia fasciata pictiventris	1	IN	J
5/2/2014	5	w	3	WB	on_road	Nerodia fasciata pictiventris	1	IN	A
10/29/2013	10	w	30	EB	on_road	Nerodia fasciata pictiventris	1	IN	J
11/8/2013	11	w	9	WB	on_road	Nerodia fasciata pictiventris	1	IN	A
11/12/2013	11	w	35	EB	on_road	Nerodia fasciata pictiventris	1	IN	J
11/15/2013	11	w	35	WB	on_road	Nerodia fasciata pictiventris	1	IN	J
11/18/2013	11	w	9	EB	shoulder	Nerodia fasciata pictiventris	1	IN	A
11/18/2013	11	w	89	EB	on_road	Nerodia fasciata pictiventris	1	IN	IN
9/16/2013	9	w	17		on_road	Nerodia spp.	1		
9/20/2013	9	w	4	EB	on_road	Nerodia spp.	1		
1/25/2013	1	w	24	WB	on_road	other	1	IN	IN
2/22/2013	2	w	46	WB	on_road	other	1	IN	IN
3/12/2013	3	w	12	WB	on_road	other	1	IN	IN
3/12/2013	3	w	22	EB	on_road	other	1	IN	IN

Appendix A-3. (cont'd)

Date	Month	Mode	ID	Lane	Location	Species	Number	Sex	Age Class
3/26/2013	3	w	81	WB	on_road	other	1	IN	IN
10/25/2013	10	w	41	EB	on_road	other	1	IN	IN
11/5/2013	11	w	15	WB	on_road	other	1	IN	IN
11/5/2013	11	w	47	WB	on_road	other	1	IN	IN
11/5/2013	11	w	57	EB	on_road	other	1	IN	IN
11/8/2013	11	w	27	EB	on_road	other	1	IN	IN
5/9/2014	5	w	66	WB	shoulder	Otus asio	1	IN	A
11/5/2013	11	w	36	WB	shoulder	Otus asio	1	IN	A
12/10/2013	12	w	32	EB	shoulder	Parulidae	1	IN	A
12/27/2013	12	d	32	WB	on_road	Polioptila caerulea	1	IN	IN
1/18/2014	1	w	53	EB	shoulder	Procyon lotor	1	IN	A
1/27/2014	1	w	31	EB	shoulder	Procyon lotor	1	IN	A
1/19/2015	1	d	31	WB		Procyon lotor	1	IN	A
2/25/2013	2	w	45	WB	shoulder	Procyon lotor	1	IN	A
2/25/2015	2	d	50	WB	on_road	Procyon lotor	1	IN	A
3/3/2014	3	w	60	EB	shoulder	Procyon lotor	1	IN	IN
3/28/2014	3	w	63	WB	on_road	Procyon lotor	1	IN	A
4/30/2013	4	d	31	EB	shoulder	Procyon lotor	1	IN	A
5/10/2013	5	w	59	EB	shoulder	Procyon lotor	1	IN	A
5/15/2014	5	w	79	EB	bike lane	Procyon lotor	1	IN	A
5/26/2014	5	d	57	WB	shoulder	Procyon lotor	1	IN	A
5/28/2014	5	d	61	WB	shoulder	Procyon lotor	1	IN	A
5/30/2014	5	d	82	EB	on_road	Procyon lotor	1	IN	J
6/21/2013	6	d	26	EB	on_road	Procyon lotor	1	IN	A
6/25/2013	6	d	52	EB	on_road	Procyon lotor	1	IN	IN
11/1/2013	11	w	30	EB	shoulder	Procyon lotor	1	IN	A
12/5/2013	12	w	74	EB	shoulder	Procyon lotor	1	IN	IN

Appendix A-3. (cont'd)

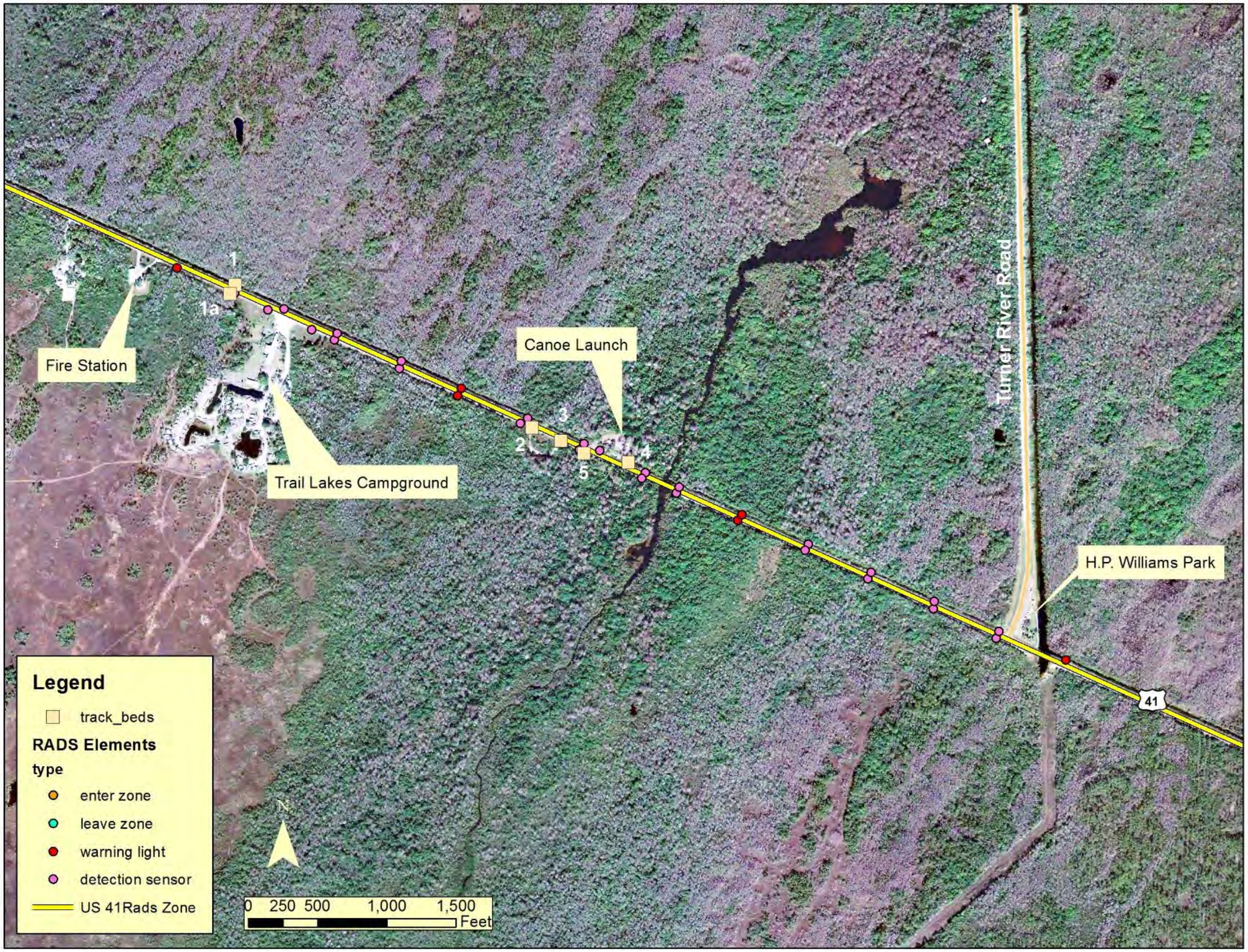
Date	Month	Mode	ID	Lane	Location	Species	Number	Sex	Age Class
1/21/2014	1	d	62	EB	bike lane	Pseudemys nelsoni	1	IN	J
4/14/2014	4	w	34	WB	on_road	Pseudemys nelsoni	1	IN	J
5/15/2014	5	w	36	EB	bike lane	Pseudemys nelsoni	2	IN	J
8/30/2013	8	w	7	WB	on_road	Pseudemys nelsoni	1	IN	J
11/15/2013	11	w	55	EB	shoulder	Pseudemys nelsoni	1	IN	A
5/3/2013	5	w	1	WB	on_road	Serpentes	1	IN	IN
8/16/2013	8	w	78	WB	shoulder	Serpentes	1	IN	J
9/12/2013	9	w	1	WB	on_road	Serpentes	1		
9/16/2013	9	w	16		on_road	Serpentes	1		
9/20/2013	9	w	10	EB	on_road	Serpentes	1		A
9/20/2013	9	w	15	EB	on_road	Serpentes	1		J
9/20/2013	9	w	24	EB	on_road	Serpentes	1		J
11/8/2013	11	w	19	EB	on_road	Serpentes	1	IN	A
11/15/2013	11	w	44	EB	shoulder	Serpentes	1	IN	A
11/22/2013	11	w	9	WB	on_road	Serpentes	1	IN	A
12/2/2013	12	w	21	EB	shoulder	Serpentes	1	IN	IN
1/25/2013	1	w	27	WB	shoulder	Sistrurus miliarius barbouri	1	IN	J
9/20/2013	9	w	29	WB	on_road	Sistrurus miliarius barbouri	1		J
11/8/2013	11	w	44	WB	on_road	Sylvilagus palustris	1	IN	IN
2/5/2013	2	w	46	EB	on_road	Sylvilagus spp.	1	IN	IN
1/25/2013	1	w	25	WB	shoulder	Testudines	1	IN	IN
2/1/2013	2	w	33	EB	shoulder	Testudines	1	IN	J
9/16/2013	9	w	55	EB	on_road	Testudines	1		
9/20/2013	9	w	14	EB	on_road	Testudines	1		J
9/20/2013	9	w	59	EB	on_road	Testudines	1		J
11/26/2013	11	w	21	WB	on_road	Testudines	1	IN	IN
11/29/2013	11	w	35	EB	on_road	Testudines	1	IN	IN

Appendix A-3. (cont'd)

Date	Month	Mode	ID	Lane	Location	Species	Number	Sex	Age Class
11/29/2013	11	w	43	EB	bike lane	Testudines	1	IN	IN
1/25/2013	1	w	18	WB	shoulder	Thamnophis s. sirtalis	1	IN	IN
1/9/2014	1	w	2	WB	bike lane	Thamnophis s. sirtalis	1	IN	A
2/25/2013	2	w	43	WB	shoulder	Thamnophis s. sirtalis	1	IN	J
6/21/2013	6	d	37	EB	on_road	Thamnophis s. sirtalis	15	IN	J
10/29/2013	10	w	20	WB	on_road	Thamnophis s. sirtalis	1	IN	A
10/29/2013	10	w	21	EB	on_road	Thamnophis s. sirtalis	1	IN	A
11/1/2013	11	w	44	WB	on_road	Thamnophis s. sirtalis	1	IN	A
11/1/2013	11	w	45	WB	bike lane	Thamnophis s. sirtalis	1	IN	A
11/5/2013	11	w	11	WB	bike lane	Thamnophis s. sirtalis	1	IN	A
11/8/2013	11	w	46	EB	on_road	Thamnophis s. sirtalis	1	IN	A
11/15/2013	11	w	11	WB	on_road	Thamnophis s. sirtalis	1	IN	A
11/15/2013	11	w	22	EB	shoulder	Thamnophis s. sirtalis	1	IN	A
11/18/2013	11	w	10	WB	on_road	Thamnophis s. sirtalis	1	IN	A
11/29/2013	11	w	16	WB	bike lane	Thamnophis s. sirtalis	1	IN	A
12/5/2013	12	w	22	WB	on_road	Thamnophis s. sirtalis	1	IN	A
11/8/2013	11	w	14	WB	bike lane	Thamnophis sauritus sackenii	1	IN	A
11/15/2013	11	w	68	EB	bike lane	Thamnophis sauritus sackenii	1	IN	A

Notes: Frogs were excluded from this table. Because there was nearly 750 records of frog road-kills, it wasn't practical to include them in this list. This data can be provided in digital format if needed.

Appendix A-4. Track Records by Track Bed Station (2013 – 2015). Below is a map of track bed locations that correspond to the ensuing table.



Appendix A-4. Track Records by Track Bed Station (2013 – 2015). Note: Includes RADS Target Species Only.

Date	Month	Track Bed	Side of Road	Soil Moisture	Species	Number	Travel Direction
5/12/2014	5	1	N	dry	Alligator mississippiensis	1	N
2/8/2013	2	1	N	dry	Ardea herodias	1	S
2/12/2013	2	1	N	dry	Ardea herodias	1	N
2/12/2013	2	1	N	dry	Ardea herodias	1	S
2/28/2013	2	1	N	wet	Ardea herodias	1	S
3/15/2013	3	1	N	dry	Ardea herodias	1	N
10/19/2013	10	1	N	dry	Ardea herodias	1	W
10/22/2013	10	1	N	moist	Ardea herodias	1	N
10/22/2013	10	1	N	moist	Ardea herodias	1	S
10/25/2013	10	1	N	dry	Ardea herodias	1	N
10/25/2013	10	1	N	dry	Ardea herodias	1	W
10/29/2013	10	1	N	dry	Ardea herodias	1	N
10/29/2013	10	1	N	dry	Ardea herodias	1	S
11/12/2013	11	1	N	dry	Ardea herodias	1	IN
1/3/2014	1	1	N	dry	Aves	1	E
1/3/2014	1	1	N	dry	Aves	1	N
1/18/2014	1	1	N	dry	Aves	1	E
1/18/2014	1	1	N	dry	Aves	1	W
2/10/2014	2	1	N	dry	Aves	2	E
3/14/2014	3	1	N	dry	Aves	1	E
3/14/2014	3	1	N	dry	Aves	1	W
3/17/2014	3	1	N	dry	Aves	1	E
3/24/2014	3	1	N	dry	Aves	1	E
4/14/2014	4	1	N	moist	Aves	2	N
4/17/2014	4	1	N	dry	Aves	1	N
4/29/2014	4	1	N	dry	Aves	1	E
5/2/2014	5	1	N	dry	Aves	1	E
12/5/2013	12	1	N	dry	Aves	2	W
12/10/2013	12	1	N	dry	Aves	1	E
12/13/2013	12	1	N	dry	Aves	2	W
12/17/2013	12	1	N	dry	Aves	1	N
12/20/2013	12	1	N	dry	Aves	1	W
12/20/2013	12	1	N	dry	Aves	1	N
12/20/2013	12	1	N	dry	Aves	1	W
12/24/2013	12	1	N	dry	Aves	1	IN
12/27/2013	12	1	N	dry	Aves	1	N
12/27/2013	12	1	N	dry	Aves	1	W
12/27/2013	12	1	N	dry	Aves	1	E
2/19/2013	2	1	N	moist	Canidae	1	S
3/29/2013	3	1	N	dry	Canidae	1	S
4/2/2013	4	1	N	dry	Canidae	1	S
4/26/2013	4	1	N	dry	Canidae	1	S

Appendix A-4. (cont'd)

Date	Month	Track Bed	Side of Road	Soil Moisture	Species	Number	Travel Direction
7/9/2013	7	1	N	moist	Canidae	1	N
11/12/2013	11	1	N	dry	Canidae	1	S
11/18/2013	11	1	N	dry	Canidae	1	N
2/24/2014	2	1	N	dry	Canis latrans	1	S
3/3/2014	3	1	N	dry	Canis latrans	1	S
5/17/2013	5	1	N	dry	Canis latrans	1	N
6/23/2013	6	1	N	moist	Canis latrans	1	N
1/9/2014	1	1	N	wet	Lynx rufus	1	S
1/14/2014	1	1	N	dry	Lynx rufus	1	N
1/21/2014	1	1	N	wet	Lynx rufus	1	S
2/19/2013	2	1	N	moist	Lynx rufus	1	S
2/22/2013	2	1	N	dry	Lynx rufus	1	N
2/17/2014	2	1	N	dry	Lynx rufus	1	S
2/21/2014	2	1	N	dry	Lynx rufus	1	S
2/24/2014	2	1	N	dry	Lynx rufus	1	S
3/5/2013	3	1	N	moist	Lynx rufus	1	N
3/8/2013	3	1	N	dry	Lynx rufus	1	S
3/15/2013	3	1	N	dry	Lynx rufus	1	N
3/19/2013	3	1	N	wet	Lynx rufus	1	S
3/10/2014	3	1	N	dry	Lynx rufus	1	S
3/14/2014	3	1	N	dry	Lynx rufus	1	N
3/24/2014	3	1	N	dry	Lynx rufus	1	N
3/31/2014	3	1	N	wet	Lynx rufus	1	S
4/6/2013	4	1	N	wet	Lynx rufus	1	N
4/19/2013	4	1	N	dry	Lynx rufus	1	N
4/26/2013	4	1	N	dry	Lynx rufus	1	N
4/26/2013	4	1	N	dry	Lynx rufus	1	S
4/17/2014	4	1	N	dry	Lynx rufus	1	S
4/1/2015	4	1	N	dry	Lynx rufus	4	N
5/14/2013	5	1	N	dry	Lynx rufus	1	S
5/17/2013	5	1	N	dry	Lynx rufus	1	N
5/20/2014	5	1	N	dry	Lynx rufus	1	S
5/23/2014	5	1	N	dry	Lynx rufus	1	S
5/29/2014	5	1	N	wet	Lynx rufus	1	S
6/15/2013	6	1	N	moist	Lynx rufus	1	N
6/18/2013	6	1	N	dry	Lynx rufus	1	N
6/18/2013	6	1	N	dry	Lynx rufus	1	N
6/23/2014	6	1	N	dry	Lynx rufus	1	S
8/3/2013	8	1	N	dry	Lynx rufus	1	S
8/4/2013	8	1	N	moist	Lynx rufus	1	S
10/29/2013	10	1	N	dry	Lynx rufus	1	N
10/29/2013	10	1	N	dry	Lynx rufus	1	S

Appendix A-4. (cont'd)

Date	Month	Track Bed	Side of Road	Soil Moisture	Species	Number	Travel Direction
11/5/2013	11	1	N	dry	Lynx rufus	1	S
11/12/2013	11	1	N	dry	Lynx rufus	1	S
11/12/2013	11	1	N	dry	Lynx rufus	1	N
12/2/2013	12	1	N	dry	Lynx rufus	1	S
12/10/2013	12	1	N	dry	Lynx rufus	1	N
12/20/2013	12	1	N	dry	Lynx rufus	1	N
12/12/2014	12	1	N	dry	Lynx rufus	6	N
12/29/2014	12	1	N	dry	Lynx rufus	2	S
2/2/2015	2	1	N	dry	Odocoileus virginianus	8	S
4/21/2014	4	1	N	wet	Odocoileus virginianus	2	N
4/24/2014	4	1	N	dry	Odocoileus virginianus	2	S
7/4/2014	7	1	N	moist	Odocoileus virginianus	1	S
7/10/2014	7	1	N	wet	Odocoileus virginianus	2	S
7/15/2014	7	1	N	wet	Odocoileus virginianus	1	S
9/19/2014	9	1	N	wet	Odocoileus virginianus	4	N
1/3/2014	1	1	N	dry	Puma concolor coryi	1	N
1/3/2014	1	1	N	dry	Puma concolor coryi	2	S
1/9/2014	1	1	N	wet	Puma concolor coryi	1	N
1/14/2014	1	1	N	dry	Puma concolor coryi	1	S
1/21/2014	1	1	N	wet	Puma concolor coryi	1	S
1/27/2014	1	1	N	dry	Puma concolor coryi	1	S
2/6/2014	2	1	N	dry	Puma concolor coryi	1	S
2/6/2014	2	1	N	dry	Puma concolor coryi	1	S
2/24/2014	2	1	N	dry	Puma concolor coryi	1	S
3/10/2014	3	1	N	dry	Puma concolor coryi	1	N
3/28/2014	3	1	N	dry	Puma concolor coryi	1	N
3/20/2015	3	1	N	dry	Puma concolor coryi	1	N
4/9/2013	4	1	N	dry	Puma concolor coryi	1	S
4/30/2013	4	1	N	wet	Puma concolor coryi	1	S
4/11/2014	4	1	N	dry	Puma concolor coryi	1	N
5/10/2013	5	1	N	dry	Puma concolor coryi	1	N
5/14/2013	5	1	N	dry	Puma concolor coryi	1	S
5/14/2013	5	1	N	dry	Puma concolor coryi	1	S
5/24/2013	5	1	N	moist	Puma concolor coryi	1	N
5/28/2013	5	1	N	moist	Puma concolor coryi	1	N
5/2/2014	5	1	N	dry	Puma concolor coryi	1	S
5/12/2014	5	1	N	dry	Puma concolor coryi	1	N
5/20/2014	5	1	N	dry	Puma concolor coryi	1	S
6/7/2013	6	1	N	wet	Puma concolor coryi	1	N
6/12/2013	6	1	N	moist	Puma concolor coryi	1	S
6/18/2014	6	1	N	wet	Puma concolor coryi	1	N
6/18/2014	6	1	N	wet	Puma concolor coryi	1	S

Appendix A-4. (cont'd)

Date	Month	Track Bed	Side of Road	Soil Moisture	Species	Number	Travel Direction
7/16/2013	7	1	N	moist	Puma concolor coryi	1	N
10/16/2013	10	1	N	dry	Puma concolor coryi	1	S
10/6/2014	10	1	N	dry	Puma concolor coryi	4	N
11/5/2013	11	1	N	dry	Puma concolor coryi	1	S
12/10/2013	12	1	N	dry	Puma concolor coryi	1	S
12/17/2013	12	1	N	dry	Puma concolor coryi	1	N
12/20/2013	12	1	N	dry	Puma concolor coryi	1	S
12/20/2013	12	1	N	dry	Puma concolor coryi	1	N
12/20/2013	12	1	N	dry	Puma concolor coryi	1	S
12/24/2013	12	1	N	dry	Puma concolor coryi	1	S
12/24/2013	12	1	N	dry	Puma concolor coryi	1	N
12/27/2013	12	1	N	dry	Puma concolor coryi	1	S
1/2/2015	1	1	N	moist	Ursus americanus floridanus	7	S
4/12/2013	4	1	N	dry	Ursus americanus floridanus	1	S
4/14/2014	4	1	N	moist	Ursus americanus floridanus	1	S
4/21/2014	4	1	N	wet	Ursus americanus floridanus	1	S
5/17/2013	5	1	N	dry	Ursus americanus floridanus	1	S
5/23/2014	5	1	N	dry	Ursus americanus floridanus	1	S
5/23/2014	5	1	N	dry	Ursus americanus floridanus	1	S
6/25/2013	6	1	N	moist	Ursus americanus floridanus	1	S
11/5/2013	11	1	N	dry	Ursus americanus floridanus	1	S
11/7/2014	11	1	N	dry	Ursus americanus floridanus	3	S
11/12/2014	11	1	N	moist	Ursus americanus floridanus	2	S
11/17/2014	11	1	N	dry	Ursus americanus floridanus	4	N
12/24/2013	12	1	N	dry	Ursus americanus floridanus	1	S
12/5/2014	12	1	N	dry	Ursus americanus floridanus	1	S
3/17/2014	3	2	S	dry	Aves	1	W
1/27/2014	1	2	S	dry	Canidae	1	E
6/12/2013	6	2	S	moist	Canidae	1	W
6/28/2013	6	2	S	dry	Canidae	1	W
7/9/2013	7	2	S	moist	Canidae	1	W
7/25/2013	7	2	S	dry	Canidae	1	W
1/21/2014	1	2	S	wet	Canis latrans	1	E
5/6/2014	5	2	S	dry	Canis latrans	1	E
6/5/2014	6	2	S	moist	Canis latrans	1	S
6/5/2014	6	2	S	moist	Canis latrans	1	W
11/12/2014	11	2	S	moist	Canis latrans	4	W
11/14/2014	11	2	S	dry	Canis latrans	9	E
5/24/2013	5	2	S	moist	Lynx rufus	1	W
6/12/2013	6	2	S	moist	Lynx rufus	1	W
6/25/2013	6	2	S	dry	Lynx rufus	1	E
7/31/2013	7	2	S	dry	Lynx rufus	1	W

Appendix A-4. (cont'd)

Date	Month	Track Bed	Side of Road	Soil Moisture	Species	Number	Travel Direction
8/3/2013	8	2	S	dry	Lynx rufus	1	W
8/30/2013	8	2	S	moist	Lynx rufus	1	E
11/28/2014	11	2	S	dry	Lynx rufus	6	E
12/1/2014	12	2	S	dry	Lynx rufus	6	W
5/24/2013	5	2	S	moist	Odocoileus virginianus	2	W
7/16/2013	7	2	S	dry	Odocoileus virginianus	1	E
10/29/2013	10	2	S	dry	Odocoileus virginianus	1	S
11/12/2013	11	2	S	dry	Odocoileus virginianus	1	S
12/5/2014	12	2	S	dry	Ursus americanus floridanus	6	E
12/17/2014	12	2	S	dry	Ursus americanus floridanus	4	E
5/23/2014	5	3	S	dry	Alligator mississippiensis	1	E
3/14/2014	3	3	S	dry	Aves	1	E
1/27/2014	1	3	S	dry	Canidae	1	E
3/29/2013	3	3	S	dry	Canidae	1	S
3/29/2013	3	3	S	dry	Canidae	1	N
4/19/2013	4	3	S	dry	Canidae	1	E
5/7/2013	5	3	S	dry	Canidae	1	E
5/10/2013	5	3	S	dry	Canidae	1	W
6/12/2013	6	3	S	moist	Canidae	1	E
6/28/2013	6	3	S	moist	Canidae	1	W
6/5/2014	6	3	S	moist	Canidae	1	W
7/9/2013	7	3	S	moist	Canidae	1	E
7/9/2013	7	3	S	moist	Canidae	2	W
7/9/2013	7	3	S	moist	Canidae	1	W
8/4/2013	8	3	S	moist	Canidae	1	E
1/9/2014	1	3	S	wet	Canis latrans	1	W
1/9/2014	1	3	S	wet	Canis latrans	1	N
1/14/2014	1	3	S	dry	Canis latrans	1	E
1/18/2014	1	3	S	dry	Canis latrans	1	W
3/19/2013	3	3	S	wet	Canis latrans	1	N
4/17/2014	4	3	S	dry	Canis latrans	1	E
7/13/2013	7	3	S	wet	Canis latrans	1	E
7/16/2013	7	3	S	moist	Canis latrans	1	E
7/25/2013	7	3	S	dry	Canis latrans	1	E
7/25/2013	7	3	S	dry	Canis latrans	1	W
10/16/2013	10	3	S	dry	Canis latrans	2	E
11/12/2014	11	3	S	moist	Canis latrans	4	W
12/20/2013	12	3	S	dry	Canis latrans	1	S
12/20/2013	12	3	S	dry	Canis latrans	1	W
2/5/2013	2	3	S	dry	Lynx rufus	1	S
4/24/2014	4	3	S	dry	Lynx rufus	1	E
6/15/2013	6	3	S	moist	Lynx rufus	1	N

Appendix A-4. (cont'd)

Date	Month	Track Bed	Side of Road	Soil Moisture	Species	Number	Travel Direction
6/15/2013	6	3	S	moist	Lynx rufus	1	S
6/25/2013	6	3	S	moist	Lynx rufus	1	E
6/25/2013	6	3	S	moist	Lynx rufus	1	W
7/19/2013	7	3	S	wet	Lynx rufus	1	E
7/31/2013	7	3	S	dry	Lynx rufus	1	W
8/3/2013	8	3	S	dry	Lynx rufus	1	W
8/3/2013	8	3	S	dry	Lynx rufus	1	E
10/22/2013	10	3	S	dry	Lynx rufus	1	E
10/22/2013	10	3	S	dry	Lynx rufus	1	E
11/5/2013	11	3	S	dry	Lynx rufus	1	W
11/28/2014	11	3	S	dry	Lynx rufus	4	E
12/1/2014	12	3	S	dry	Lynx rufus	17	W
2/15/2013	2	3	S	wet	Odocoileus virginianus	1	S
3/19/2013	3	3	S	wet	Odocoileus virginianus	1	E
3/19/2013	3	3	S	wet	Odocoileus virginianus	1	W
4/6/2013	4	3	S	wet	Odocoileus virginianus	1	N
4/6/2013	4	3	S	wet	Odocoileus virginianus	2	S
7/16/2013	7	3	S	moist	Odocoileus virginianus	1	S
7/16/2013	7	3	S	moist	Odocoileus virginianus	1	N
7/16/2013	7	3	S	moist	Odocoileus virginianus	1	N
7/16/2013	7	3	S	moist	Odocoileus virginianus	1	N
7/16/2013	7	3	S	moist	Odocoileus virginianus	1	N
7/22/2013	7	3	S	moist	Odocoileus virginianus	2	N
7/25/2013	7	3	S	dry	Odocoileus virginianus	1	N
7/31/2013	7	3	S	dry	Odocoileus virginianus	1	S
11/12/2013	11	3	S	dry	Odocoileus virginianus	1	N
1/6/2014	1	3	S	wet	Puma concolor coryi	1	W
2/6/2014	2	3	S	dry	Puma concolor coryi	1	S
2/6/2014	2	3	S	dry	Puma concolor coryi	1	N
4/7/2014	4	3	S	dry	Puma concolor coryi	1	E
5/6/2014	5	3	S	dry	Puma concolor coryi	1	E
11/3/2014	11	3	S	dry	Puma concolor coryi	3	N
12/10/2013	12	3	S	dry	Puma concolor coryi	1	N
12/20/2013	12	3	S	dry	Puma concolor coryi	1	N
12/5/2014	12	3	S	dry	Ursus americanus floridanus	2	E
12/12/2014	12	3	S	dry	Ursus americanus floridanus	6	E
12/17/2014	12	3	S	dry	Ursus americanus floridanus	6	E
2/22/2013	2	4	N	dry	Ardea herodias	3	S
2/22/2013	2	4	N	dry	Ardea herodias	1	N
11/18/2013	11	4	N	dry	Aves	1	E
4/2/2013	4	4	N	dry	Canidae	1	W
5/10/2013	5	4	N	dry	Canidae	1	S

Appendix A-4. (cont'd)

Date	Month	Track Bed	Side of Road	Soil Moisture	Species	Number	Travel Direction
7/31/2013	7	4	N	dry	Canidae	1	S
8/4/2013	8	4	N	moist	Canidae	1	S
1/6/2014	1	4	N	wet	Canis latrans	1	S
1/14/2014	1	4	N	dry	Canis latrans	1	S
1/21/2014	1	4	N	wet	Canis latrans	1	S
3/31/2014	3	4	N	wet	Canis latrans	1	S
5/7/2013	5	4	N	dry	Canis latrans	1	N
11/5/2013	11	4	N	dry	Canis latrans	1	S
11/8/2013	11	4	N	dry	Canis latrans	1	S
11/8/2013	11	4	N	dry	Canis latrans	1	W
11/18/2013	11	4	N	dry	Canis latrans	1	S
2/5/2013	2	4	N	dry	Lynx rufus	1	N
2/22/2013	2	4	N	dry	Lynx rufus	1	E
8/3/2013	8	4	N	dry	Lynx rufus	1	N
8/3/2013	8	4	N	dry	Lynx rufus	1	S
8/3/2013	8	4	N	dry	Lynx rufus	1	W
8/30/2013	8	4	N	moist	Lynx rufus	1	S
10/22/2013	10	4	N	dry	Lynx rufus	1	E
3/5/2013	3	4	N	moist	Odocoileus virginianus	1	N
4/6/2013	4	4	N	wet	Odocoileus virginianus	1	N
4/6/2013	4	4	N	wet	Odocoileus virginianus	1	N
10/10/2014	10	4	N	dry	Odocoileus virginianus	2	E
1/29/2013	1	4	N	dry	Puma concolor coryi	1	S
3/10/2014	3	4	N	dry	Puma concolor coryi	1	S
4/24/2014	4	4	N	dry	Puma concolor coryi	1	S
5/6/2014	5	4	N	dry	Puma concolor coryi	1	S
12/10/2013	12	4	N	dry	Puma concolor coryi	1	S
12/31/2013	12	4	N	dry	Puma concolor coryi	1	W
11/5/2013	11	4	N	dry	Ursus americanus floridanus	1	N
3/31/2014	3	5	S	wet	Canis latrans	1	W
10/16/2013	10	5	S	dry	Canis latrans	1	E
3/24/2014	3	5	S	dry	Lynx rufus	1	S
6/14/2014	6	5	S	wet	Lynx rufus	1	S
10/22/2013	10	5	S	dry	Lynx rufus	1	S
10/22/2013	10	5	S	dry	Lynx rufus	1	S
9/26/2013	9	5	S	moist	Odocoileus virginianus	1	N
10/22/2013	10	5	S	dry	Odocoileus virginianus	1	S
11/8/2013	11	5	S	dry	Odocoileus virginianus	1	N
11/1/2013	11	5	S	dry	Puma concolor coryi	1	W
12/5/2014	12	5	S	dry	Ursus americanus floridanus	3	E
12/12/2014	12	5	S	dry	Ursus americanus floridanus	2	E
10/19/2013	10	1a	S	dry	Ardea herodias	1	E

Appendix A-4. (cont'd)

Date	Month	Track Bed	Side of Road	Soil Moisture	Species	Number	Travel Direction
1/6/2014	1	1a	S	wet	Aves	1	E
7/9/2013	7	1a	S	moist	Canidae	1	E
7/9/2013	7	1a	S	moist	Canidae	2	W
1/18/2014	1	1a	S	dry	Canis latrans	1	W
1/30/2014	1	1a	S	wet	Canis latrans	1	W
2/3/2014	2	1a	S	moist	Canis latrans	1	E
5/6/2014	5	1a	S	dry	Canis latrans	1	E
12/13/2013	12	1a	S	dry	Canis latrans	1	W
1/14/2014	1	1a	S	dry	Lynx rufus	1	N
8/4/2013	8	1a	S	moist	Lynx rufus	1	S
10/29/2013	10	1a	S	dry	Lynx rufus	2	N
10/29/2013	10	1a	S	dry	Lynx rufus	1	S
10/3/2014	10	1a	S	dry	Lynx rufus	4	N
10/13/2014	10	1a	S	dry	Lynx rufus	2	N
10/20/2014	10	1a	S	dry	Lynx rufus	2	S
12/13/2013	12	1a	S	dry	Lynx rufus	1	E
12/12/2014	12	1a	S	dry	Lynx rufus	2	N
1/19/2015	1	1a	S	dry	Odocoileus virginianus	2	S
1/21/2015	1	1a	S	dry	Odocoileus virginianus	4	S
1/28/2015	1	1a	S	dry	Odocoileus virginianus	2	S
3/4/2015	3	1a	S	dry	Odocoileus virginianus	6	S
3/13/2015	3	1a	S	dry	Odocoileus virginianus	4	S
3/16/2015	3	1a	S	dry	Odocoileus virginianus	2	S
6/18/2013	6	1a	S	dry	Odocoileus virginianus	1	S
6/28/2013	6	1a	S	moist	Odocoileus virginianus	1	E
9/26/2013	9	1a	S	moist	Odocoileus virginianus	1	S
10/8/2014	10	1a	S	dry	Odocoileus virginianus	4	W
10/17/2014	10	1a	S	dry	Odocoileus virginianus	6	E
5/24/2013	5	1a	S	moist	Puma concolor coryi	1	N
6/25/2013	6	1a	S	moist	Ursus americanus floridanus	1	S
12/1/2014	12	1a	S	dry	Ursus americanus floridanus	3	N
12/5/2014	12	1a	S	dry	Ursus americanus floridanus	4	S
9/20/2013	9	?		moist	Lynx rufus	1	IN
9/20/2013	9	?		moist	Odocoileus virginianus	1	

APPENDIX B

Comparison of RADS Sensor Data and Camera Trap Data

Appendix B-1. **Camera Trap Data and Sensor Triggers by Month (April 2013 – April 2015).** Data showing how each RADS sensor detected animal movement matched against camera data by month. Success rate is the percent of total images that matched sensor triggers; false positive rate equals the percent of total sensor triggers not represented by image-sensor matches.

Month	Year	Sensor	Total images	Total triggers	Image-trigger matches	Success rate (%)	False positives rate (%)
Apr	2013	N-D07-W	23	140	23	100%	83.6%
Apr	2013	N-D19-E	0	0	0	na	na
Apr	2013	N-D19-W	0	295	0	na	100%
May	2013	N-D07-W	14	332	13	92.9%	96.1%
May	2013	N-D19-E	0	0	0	na	na
May	2013	N-D19-W	0	2,225	0	na	100%
Jun	2013	N-D07-W	6	52	5	83.3%	90.4%
Jun	2013	N-D19-E	7	0	0	0%	na
Jun	2013	N-D19-W	2	370	0	0%	100%
Jul	2013	N-D07-W	1	25	1	100%	96%
Jul	2013	N-D19-E	6	0	0	0%	na
Jul	2013	N-D19-W	7	126	0	0%	100%
Aug	2013	N-D07-W	8	185	4	50%	97.8%
Aug	2013	N-D19-E	4	0	0	0%	na
Aug	2013	N-D19-W	7	264	1	14.3%	99.6%
Sep	2013	N-D07-W	20	1,155	15	75%	98.7%
Sep	2013	N-D19-E	1	6	0	0%	100%
Sep	2013	N-D19-W	6	222	1	16.7%	99.5%
Oct	2013	N-D07-W	10	937	8	80%	99.1%
Oct	2013	N-D19-E	1	26	0	0%	100%
Oct	2013	N-D19-W	2	220	0	0%	100%
Nov	2013	N-D07-W	30	122	25	83.3%	79.5%
Nov	2013	N-D19-E	3	42	1	33.3%	97.6%
Nov	2013	N-D19-W	1	309	0	0%	100%
Dec	2013	N-D07-W	28	391	6	21.4%	98.5%
Dec	2013	N-D19-E	1	31	0	0%	100%
Dec	2013	N-D19-W	6	448	0	0%	100%
Jan	2014	N-D07-W	10	411	8	80%	98.1%
Jan	2014	N-D19-E	2	31	1	50%	96.8%
Jan	2014	N-D19-W	0	169	0	na	100%
Feb	2014	N-D07-W	20	1,180	18	90%	98.5%
Feb	2014	N-D19-E	3	34	2	66.7%	94.1%
Feb	2014	N-D19-W	4	305	2	50%	99.3%

Appendix B-1. (cont'd)

Month	Year	Sensor	Total images	Total triggers	Image-trigger matches	Success rate (%)	False positives rate (%)
Mar	2014	N-D07-W	8	3,368	8	100.0%	99.8%
Mar	2014	N-D19-E	3	141	2	66.7%	98.6%
Mar	2014	N-D19-W	2	139	0	0%	100%
Apr	2014	N-D07-W	5	730	4	80%	99.5%
Apr	2014	N-D19-E	1	1,674	0	0%	100%
Apr	2014	N-D19-W	4	142	4	100%	97.2%
May	2014	N-D07-W	16	144	0	0%	100%
May	2014	N-D19-E	2	29	0	0%	100%
May	2014	N-D19-W	0	1,017	0	na	100%
Jun	2014	N-D07-W	1	185	0	0%	100%
Jun	2014	N-D19-E	0	0	0	na	na
Jun	2014	N-D19-W	0	0	0	na	na
Jun	2014	S-D06-W	1	0	0	0%	na
Jun	2014	S-D17-E	6	4	1	16.7%	75.0%
Jul	2014	N-D07-W	6	68	5	83.3%	92.6%
Jul	2014	N-D19-E	6	7	2	33.3%	71.4%
Jul	2014	N-D19-W	0	111	0	na	100%
Jul	2014	S-D06-W	2	7	1	50%	85.7%
Jul	2014	S-D17-E	20	76	15	75%	80.3%
Aug	2014	N-D07-W	4	0	0	0%	na
Aug	2014	N-D19-E	0	1	0	na	100%
Aug	2014	N-D19-W	0	1	0	na	100%
Aug	2014	S-D06-W	0	0	0	na	na
Aug	2014	S-D17-E	6	0	0	0%	na
Sep	2014	N-D07-W	2	78	1	50%	98.7%
Sep	2014	N-D19-E	1	33	0	0%	100%
Sep	2014	N-D19-W	0	378	0	na	100%
Sep	2014	S-D06-W	0	4	0	na	100%
Sep	2014	S-D17-E	11	102	0	0%	100%
Oct	2014	N-D07-W	15	444	0	0%	100%
Oct	2014	N-D19-E	3	51	0	0%	100%
Oct	2014	N-D19-W	2	207	0	0%	100%
Oct	2014	S-D06-W	4	23	0	0%	100%
Oct	2014	S-D17-E	2	37	1	50%	97.3%

Appendix B-1. (cont'd)

Month	Year	Sensor	Total images	Total triggers	Image-trigger matches	Success rate (%)	False positives rate (%)
Nov	2014	N-D07-W	14	6,792	12	85.7%	99.8%
Nov	2014	N-D19-E	6	50	6	100%	88%
Nov	2014	N-D19-W	5	271	3	60%	98.9%
Nov	2014	S-D06-W	5	26	2	40%	92.3%
Nov	2014	S-D17-E	10	48	10	100%	79.2%
Dec	2014	N-D07-W	19	735	11	57.9%	98.5%
Dec	2014	N-D19-E	0	1	0	na	100%
Dec	2014	N-D19-W	0	31	0	na	100%
Dec	2014	S-D06-W	5	27	0	0%	100%
Dec	2014	S-D17-E	6	66	5	83.3%	92.4%
Jan	2015	N-D07-W	7	72	7	100%	90.3%
Jan	2015	N-D19-E	6	222	4	66.7%	98.2%
Jan	2015	N-D19-W	1	492	1	100%	99.8%
Jan	2015	S-D06-W	42	18	2	4.8%	88.9%
Jan	2015	S-D17-E	1	17	1	100%	94.1%
Feb	2015	N-D07-W	14	710	11	78.6%	98.5%
Feb	2015	N-D19-E	6	1,296	5	83.3%	99.6%
Feb	2015	N-D19-W	9	449	4	44.4%	99.1%
Feb	2015	S-D06-W	12	30	3	25%	90%
Feb	2015	S-D17-E	0	47	0	na	100%
Mar	2015	N-D07-W	1	1,251	1	100%	99.9%
Mar	2015	N-D19-E	1	772	1	100%	99.9%
Mar	2015	N-D19-W	1	114	0	0%	100%
Mar	2015	S-D06-W	4	17	0	0%	100%
Mar	2015	S-D17-E	7	130	5	71.4%	96.2%
Apr	2015	N-D07-W	0	912	0	na	100%
Apr	2015	N-D19-E	1	37	1	100%	97.3%
Apr	2015	N-D19-W	0	205	0	na	100%
Apr	2015	S-D06-W	0	5	0	na	100%
Apr	2015	S-D17-E	1	14	0	0%	100%
		Total	**550**	**34,111**	**273**	**49.6%**	**99.2%**

Notes: There was incomplete coverage by cameras monitoring sensor sections S-D17-E and S-D06-W until mid-May 2014, so averages for those sensor sections are from June 2014 onward; Data from some months were partially missing because of system malfunctions or physical damage to equipment (see Table 4).

Appendix B-2. Total Triggers by Sensor by month, Jan 2013 – Apr 2015. A comparison of RADS sensor triggers including monthly totals night vs. day.

Sensor	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14
N-D07-W	6,540	2,017	2,227	952	499	285	291	982	6,215	6,345	588	2,320	2,949	15,396	27,962	11,648
N-D10-E	518	3,680	16,768	14,086	216	193	50	1,406	4,600	3,137	3,417	2,923	2,656	2,974	1,598	34,444
N-D10-W	738	4,909	22,491	13,389	234	120	27	2,356	49	193	5,624	581	1,947	171	323	11,631
N-D14-E	1	1	43,472	38,629	348	998	4,158	10,035	3,984	908	1,154	1,677	1,151	678	4,432	6,212
N-D14-W	985	524	901	2,271	693	7,757	2,602	83	39	2,216	5,852	1,465	9,624	14,300	36,683	49,258
N-D18-W	392	770	657	1,483	193	7,083	7,692	4,733	6,234	245	357	204	2,030	344	179	398
N-D19-E	-	-	-	-	-	-	-	-	57	247	556	317	210	435	718	14,928
N-D19-W	4,070	4,150	4,899	3,498	2,568	2,455	2,328	2,796	1,600	1,760	2,995	3,695	1,620	3,029	3,278	2,665
N-D25-E	770	472	23,127	31,803	290	2,490	76	858	267	1,386	475	381	813	-	2	24
N-D25-W	-	1	-	-	-	-	-	-	207	301	3,655	4,453	15,337	9,287	85,160	58,288
N-D29-E	1,032	2,236	11,155	8,146	3,506	11,644	28,185	10,214	228	5,562	715	24,048	37,491	1,363	1,633	10,115
N-D29-W	846	4,239	8,433	10,785	857	4,550	4,358	1,994	1,933	5,520	666	271	1,353	1,026	2,771	16,237
N-D33-W	2,724	10,724	23,289	2,479	637	1,574	6,186	2,705	6,853	1,488	405	631	95	8,730	1,069	7,841
S-D06-E	5,746	1,523	1,531	1,072	922	632	605	446	554	773	763	906	1,099	1,159	1,189	953
S-D06-W	163	134	240	225	261	543	98	127	46	180	158	68	124	88	80	105
S-D09-E	363	394	216	516	486	1,691	672	555	254	363	163	101	308	302	180	297
S-D09-W	36	588	2,042	1,142	6,032	24,062	27,014	26,266	28,884	16,974	12,452	11,454	15,100	28,676	8,709	13,209
S-D13-E	97	359	96	245	122	172	88	165	36	284	202	73	149	108	59	101
S-D13-W	88	162	99	341	72	167	120	278	68	1,061	502	51	144	516	190	95
S-D17-E	-	1	-	-	-	-	-	-	111	312	302	254	215	204	142	150
S-D17-W	192	400	284	426	246	281	230	903	155	332	308	161	197	180	232	249
S-D24-E	437	486	133	214	135	69	209	175	118	330	236	94	106	284	2,121	8,457
S-D24-W	-	1	-	2	-	-	-	-	286	2,406	2,343	1,138	2,376	5,818	18,225	28,676
S-D28-E	178	160	6	-	-	-	-	-	92	220	135	68	207	139	299	72
S-D28-W	90	87	12	-	-	-	-	-	482	2,411	113	114	130	177	46	94
S-D32-W	150	120	281	196	217	118	140	234	86	321	157	104	230	316	55	80
Total	**26,156**	**38,138**	**162,359**	**131,900**	**18,534**	**66,884**	**85,129**	**67,311**	**63,438**	**55,275**	**44,293**	**57,552**	**97,661**	**95,700**	**197,335**	**276,227**
Day Triggers	**21,381**	**32,093**	**122,247**	**105,571**	**12,582**	**39,978**	**55,430**	**38,105**	**33,658**	**40,694**	**28,789**	**35,267**	**68,399**	**74,596**	**159,754**	**230,186**
Night Triggers	**4,775**	**6,045**	**40,112**	**26,329**	**5,952**	**26,906**	**29,699**	**29,206**	**29,780**	**14,581**	**15,504**	**22,285**	**29,262**	**21,104**	**37,581**	**46,041**

Appendix B-2. (cont'd)

Sensor	May-14	Jun-14*	Jul-14^	Sep-14#	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15		Total	Percent
N-D07-W	237	1,730	1,489	405	5,055	15,088	3,425	611	3,841	4,765	3,400		**127,262**	**5.0**
N-D10-E	1,709	567	959	9,104	37,404	19,507	5,807	2,569	5,077	15,453	19,583		**210,405**	**8.3**
N-D10-W	240	147	74	79	1,646	6,167	4,004	299	79	95	724		**78,337**	**3.1**
N-D14-E	21	55	2,568	1,225	20,164	16,529	2,878	4,324	2,958	6,527	5,135		**180,222**	**7.1**
N-D14-W	50,918	36,828	24,525	7,404	28,277	26,551	28,919	29,117	31,881	36,009	35,230		**470,912**	**18.5**
N-D18-W	17	1	81	237	39,173	4,413	339	157	49	259	86		**77,806**	**3.1**
N-D19-E	37	-	136	109	242	198	10	938	6,290	6,873	2,545		**34,846**	**1.4**
N-D19-W	1,385	-	1,976	947	1,912	2,375	346	4,200	3,874	2,769	2,752		**69,942**	**2.8**
N-D25-E	866	490	873	87	1,618	1,012	925	150	361	1,346	98		**71,060**	**2.8**
N-D25-W	1,704	8,516	514	1,829	3,114	7,852	3,940	4,308	8,568	9,699	9,553		**236,286**	**9.3**
N-D29-E	370	283	619	141	11,754	6,817	3,154	1,121	609	693	10		**182,844**	**7.2**
N-D29-W	931	123	4,754	88	515	1,843	1,165	453	711	510	50		**76,982**	**3.0**
N-D33-W	469	125	481	143	7,919	16,382	2,222	1,398	750	4,786	553		**112,658**	**4.4**
S-D06-E	704	333	494	-	9	-	-	-	1	6	34		**21,454**	**0.8**
S-D06-W	26	17	66	21	93	136	122	109	156	133	83		**3,602**	**0.1**
S-D09-E	202	45	390	73	10,725	121	144	161	97	80	44		**18,943**	**0.7**
S-D09-W	6,903	2,370	5,656	-	1	-	-	-	-	-	-		**237,570**	**9.3**
S-D13-E	114	100	59	53	7,458	154	237	160	144	91	35		**10,961**	**0.4**
S-D13-W	49	202	29	43	20,970	280	268	146	480	353	52		**26,826**	**1.1**
S-D17-E	346	50	294	114	121	69	201	121	134	531	56		**3,728**	**0.1**
S-D17-W	138	76	217	2,982	98	91	127	172	107	119	44		**8,947**	**0.4**
S-D24-E	618	275	715	251	2,848	999	917	1,543	877	-	1,138		**23,785**	**0.9**
S-D24-W	16,520	8,525	24,776	16,919	25,321	19,085	16,673	40,758	14,781	-	515		**245,144**	**9.6**
S-D28-E	151	46	100	-	-	-	-	-	-	-	-		**1,873**	**0.1**
S-D28-W	60	50	49	94	67	53	129	157	267	336	449		**5,467**	**0.2**
S-D32-W	228	53	90	53	90	172	165	269	80	125	93		**4,223**	**0.2**
Total	**84,963**	**61,007**	**71,984**	**42,401**	**226,594**	**145,894**	**76,117**	**93,241**	**82,172**	**91,558**	**82,262**		**2,542,085**	
Day Triggers	**76,521**	**43,248**	**59,564**	**32,414**	**162,165**	**93,753**	**46,216**	**58,057**	**44,411**	**71,120**	**66,524**		**1,852,723**	**73**
Night Triggers	**8,442**	**17,759**	**12,420**	**9,987**	**64,429**	**52,141**	**29,901**	**35,184**	**37,761**	**20,438**	**15,738**		**689,362**	**27**

Note: Data from some months were partially missing because of system malfunctions or physical damage to equipment (see Table 4).