Assessing the Value of Current Movement Pathways of Florida Panthers that Intersect Keri and Corkscrew Roads: Identifying Location and Need for Safe Crossing Measures

Final Report

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Table of Contents

List of Tables

Table No. **Page**

List of Figures

Figure No. **Page**

EXECUTIVE SUMMARY

This study examined movement patterns and potential road crossing locations of Florida panthers and other wildlife on two county roads that subdivide important panther habitat areas and exhibit multiple panther-vehicle collisions, Keri Road (Hendry County Road 832) and Corkscrew Road (Collier/Lee County Road 850). The objectives of the study were to: 1) evaluate the importance of local movement pathways within key panther habitat areas, their deficiencies and road conflicts, and, 2) identify specific need for safe road-crossing measures and provide recommendations to improve habitat connectivity and reduce panther-vehicle conflicts.

Keri Road essentially divides the Okaloacoochee Slough State Forest into two separate habitat areas and accommodates about 450 vehicles per day. Seven panthers have died from vehicle collisions since 2004. Corkscrew Road passes through two distinct study areas characterized by public conservation lands on one side of the road and commercial agriculture and rural residential on the opposite side of the road. Traffic ranges from 4,400 to 7,800 vehicles per day. Five panther deaths have occurred on Corkscrew Road since 2009.

We deployed a total of 99 cameras along 29 road segments on Keri and Corkscrew roads. We recorded a total of 6,199 and 2,259 photo events of wildlife adjacent to Keri and Corkscrew roads, respectively between December 2017 and May 2019. Photo event count data (for target species: FL panther, black bear, bobcat, and whitetail deer) were assessed using R by fitting an N- mixture model using the package “unmarked” which fits hierarchical models to models of measures of wildlife occurrence and abundance. The number of active camera days at each site was a significant factor in the detection process and affected relative abundance estimates. Eight state process covariates (4 numerical and 4 categorical) were also evaluated.

The road segments on Keri Road where the target species were most abundant (in relative terms only) as measured by Bayesian posterior abundance estimates differed; abundance estimates for FL panthers and bobcats were highest in road segments 1, 4 and 9, black bear abundance was greatest in road segments 0, 1 and 4, while estimates for whitetail deer were highest in road segments 2, 3, and 10.

On Corkscrew Road, the top two measures of relative abundance for panthers and bobcats were both associated with road segments 11 and 14. Black bears were highest in road segment 14. Deer were most abundant in road segments 9, 10 and 12.

Recommendations regarding need and type of mitigation to address wildlife-vehicle conflicts were discussed for each individual road segment for both Keri and Corkscrew roads. Types of mitigation discussed included lighted warning signage, enhanced speed enforcement, wildlife fencing, “crosswalk” animal detection/warning systems and wildlife underpasses.

INTRODUCTION

Roads are one of the greatest threats to wildlife worldwide (van der Ree et al. 2015, Trombulak and Frissell 2000). Wildlife crossing structures are needed at carefully selected locations along roads in order to allow wildlife to successfully cross highways and maintain connectivity and gene flow within and among populations (Forman et al. 2003). Several studies have discussed methods for determining appropriate locations for crossing structures. For example, GIS-based habitat models and least-cost path analysis for species of interest, data on roadkill locations, radio telemetry, remote camera imagery, known migratory paths of animals, and animal signs such as tracks, can identify suitable sites for highway crossing structures (Smith et al. 2015, Smith and van der Ree 2015, Clevenger et al. 2002/2003, Henke et al. 2002, Lyren and Crooks 2002, Foster and Humphrey 1995). Decisions regarding the correct placement of crossing structures benefits from data on unsuccessful crossing locations (i.e., roadkills), but whenever possible should be combined with data on successful crossing locations (i.e., from radio-tracking and camera traps or tracking stations) and a broader look at the landscape context of the crossing, including the adjacent topography, vegetation, and land use. Concentrations of roadkills represent unsuccessful crossings, however, it may also represent areas where many individuals are also crossing successfully.

While many Florida panther road crossing locations in southwest Florida have been retrofitted with crossing structures to provide safe passage, many secondary roads are yet to be addressed. A previous study (Smith et al. 2006) conducted for the Florida Wildlife Federation identified additional needs on several county roads in NW Collier County, some of which have subsequently been mitigated. Several other roads in Hendry and Lee Counties also warrant such examination based on the number of road-kills, telemetry data, proximity to public conservation lands, and/or within an identified panther movement corridor. The following study examined movement patterns and potential road crossing locations of panthers and other wildlife on two county roads that subdivide important panther habitat areas and exhibit multiple panther-vehicle collisions, Keri Road (Hendry County Road 832) and Corkscrew Road (Collier/Lee County Road 850).

Study Objectives:

1) To evaluate the importance of local movement pathways within key panther habitat areas, their deficiencies and road conflicts, and
2) To identify specific need for safe road-crossing measures and provide recommendations to improve habitat connectivity/reduce panther-vehicle conflicts.

Study Areas:

Keri Road, Hendry County. Keri Road (County Road 832) essentially divides the Okaloacoochee Slough State Forest (OKSSF)(32,370 ac) into two separate habitat areas (fig. 1). Traffic volume is on avg 450 vehicle per day (FDOT Traffic Online 2019), but traffic speed on this rural road often exceeds its posted limit of 55 mph. Eight panther-vehicle collisions (7 since 2004) have resulted from high speed and other contributing factors to present a significant risk to panthers and other wildlife that regularly cross this road.

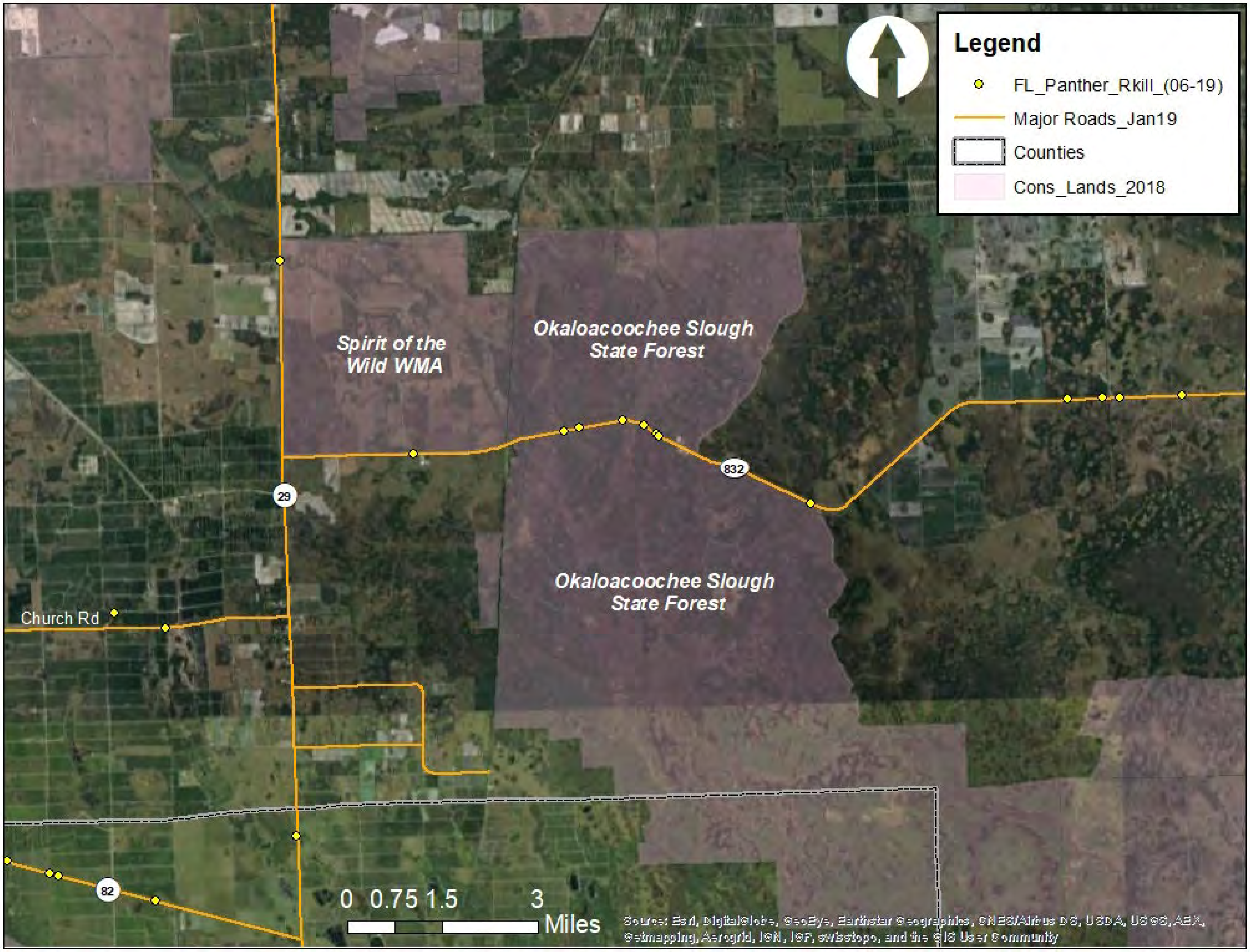

Figure 1. Keri Road (Hendry County Road 832) study area through the Okaloacoochee Slough State Forest. Florida panther road mortality locations are shown in yellow.

Adjacent to OKSSF is the 7,646 ac Spirit of the Wild WMA (SW). The OKSSF/SW conservation area is primary habitat for Florida panther and other wildlife and is a major stepping-stone for panthers to expand their range from the core of Big Cypress National Preserve (BCNP)/Florida Panther National Wildlife Refuge (FPNWR) to other substantially large conservation areas north of the Caloosahatchee River. This is illustrated in fig. 2 that shows general spatial patterns from panther telemetry- and road mortality- composite data since the mid-90s.

Land use in the study area is mostly for conservation and agriculture. The few buildings present in the area along Keri Road serve as work facilities or on-site housing for conservation land management and large cattle ranch operations. Land cover for OKSSF, SW and the Alico Ranch consists of a diverse mosaic of habitat types (fig. 3). Most commonly used land cover types were forested uplands and wetlands, followed by dry prairie and successional shrub-brush lands and semi-natural pasture areas. Common pathways used by panthers in this landscape appear to be in forested habitats along the margins of open marsh and slough habitats.

Corkscrew Road, Collier and Lee Counties. Corkscrew Road (County Road 850) passes through two distinct study areas in eastern Lee/NW Collier counties. The Lee County section is oriented from east to west and ends where it intersects Alico Road, and the Collier County section is oriented south to north terminating at State Road 82 (fig. 4). Traffic volume for the Lee County section is on avg 7,800 vehicles per day, while the Collier County section exhibits about 4,400 vehicle per day (FDOT Traffic Online 2019). Like Keri Road, traffic speed often exceeds the 55/45 mph (day/night) posted limit. These are contributing factors resulting in six panther-vehicle collisions (5 since 2009) on the Collier County section. In Lee County, two panther deaths occurred in 2006-07 near the current wildlife underpass prior to the extension of the wildlife fencing that leads to the crossing structure. High-volume, fast-moving traffic presents a significant risk to panthers and other wildlife that attempt to cross this road.

To the south and along the eastern boundary of Corkscrew Road, the Corkscrew Regional Ecosystem Watershed (CREW) and the Corkscrew Swamp Sanctuary represent the largest conservation areas in this study area, 28,175 ac and 13,440 ac, respectively (fig 4). Several other smaller conservation lands, mitigation banks and easements are located along the Lee County section of Corkscrew Road (fig. 5). This area is designated by Lee County as the Density Reduction/Groundwater Resource Area, a special planning district established to protect groundwater and address surface water storage needs.

Development proposals within the area that included creation of conservation linkages connecting the Airport/Corkscrew Mitigation Banks and Corkscrew Swamp Sanctuary (see fig. 5) were a driving factor for inclusion of this location in the panther movement/road crossing study. Panther movements and area usage in reference to these conservation areas is provided in fig. 6. The greatest concentration of panther telemetry positions is within the major protected conservation areas including the linkage across Corkscrew Road where the existing wildlife underpass is located.

Land cover consisted of a complex arrangement of habitat types and land uses (fig. 7). Land use in the study area is primarily a mix of conservation, agriculture, mining and low-density residential and rural development. Most commonly used land cover types by panthers were forested uplands and wetlands, followed by successional shrub-brush lands and semi-natural pasture areas. Most of the agriculture along Corkscrew Road consists of citrus groves—these were used with less frequency by collared panthers.

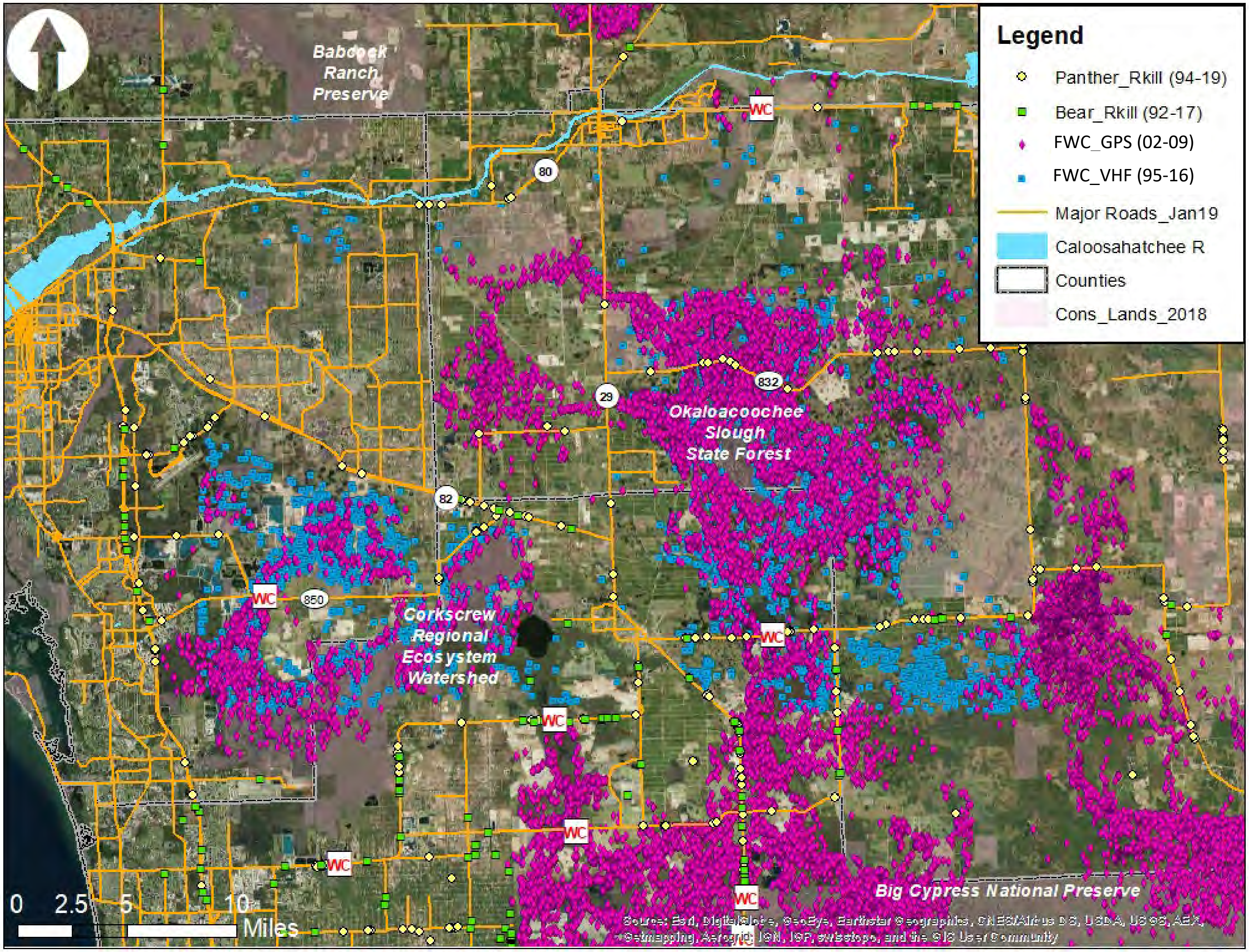

Figure 2. Telemetry concentrations and road mortalities of Florida panthers between Big Cypress National Preserve and the Caloosahatchee River (panther and bear location data provided by FWC). Constructed wildlife crossings are designated by WC.

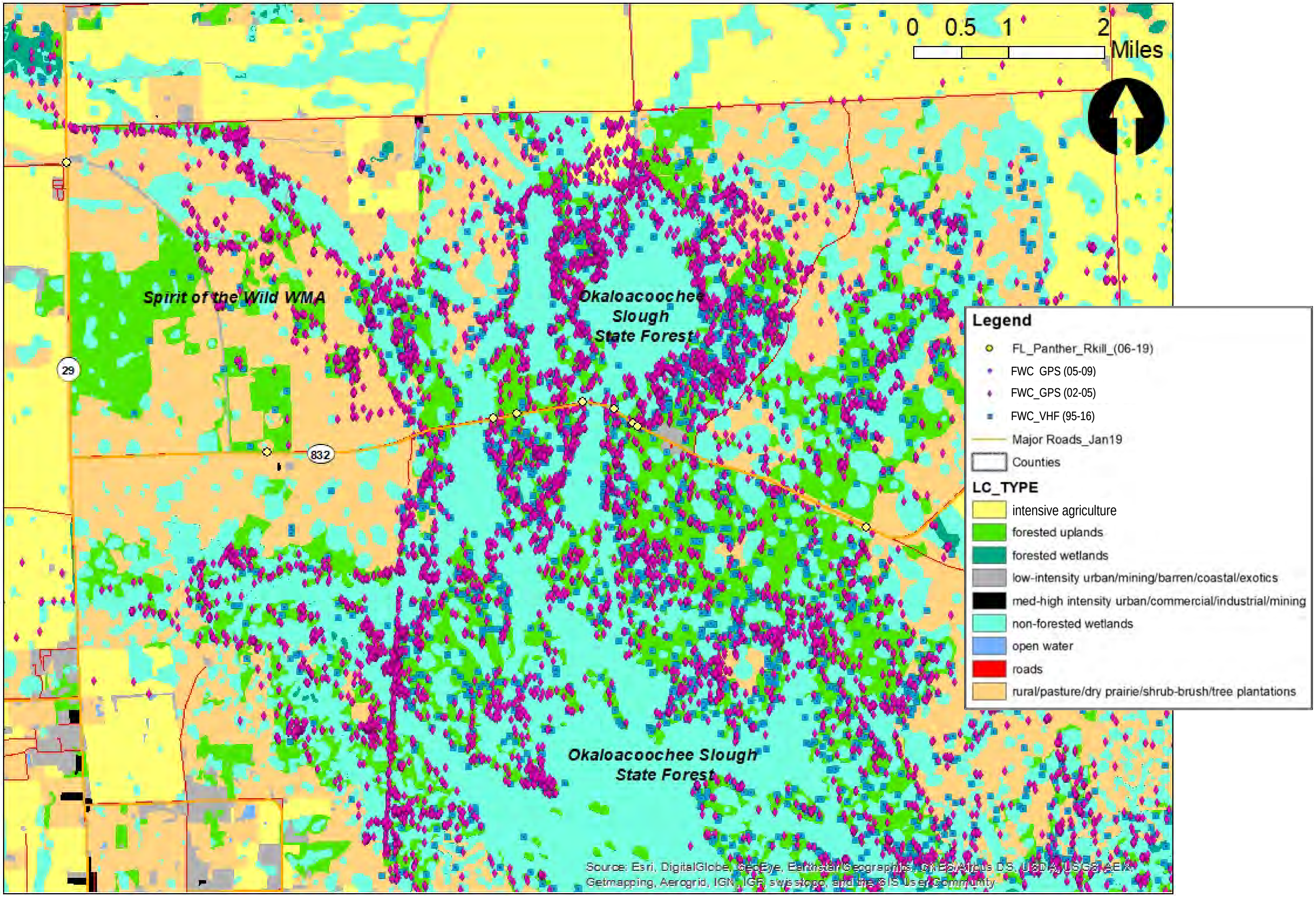

Figure 3. Land cover for the Keri Road (OKSSF/SW) study area (data: FWC 2018). For display purposes, land cover was condensed into 9 basic categories. Panther telemetry and roadkill locations are overlaid to illustrate relative use of different habitat types.

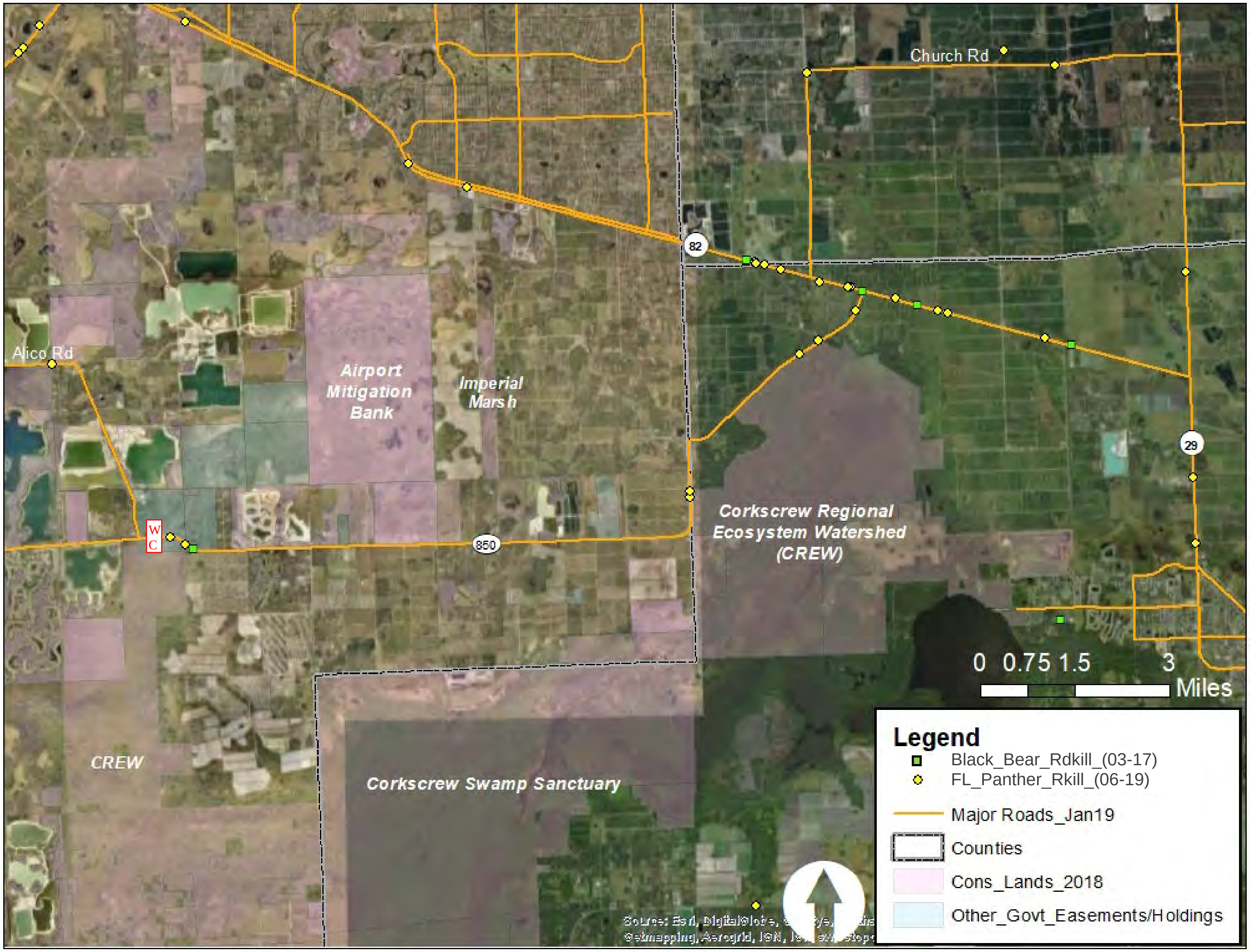

Figure 4. Corkscrew Road (Road 850) study area through the Corkscrew Regional Ecosystem Watershed. Florida panther and black bear road mortality locations are shown in yellow and green, respectively. The "WC" symbol represents a wildlife underpass.

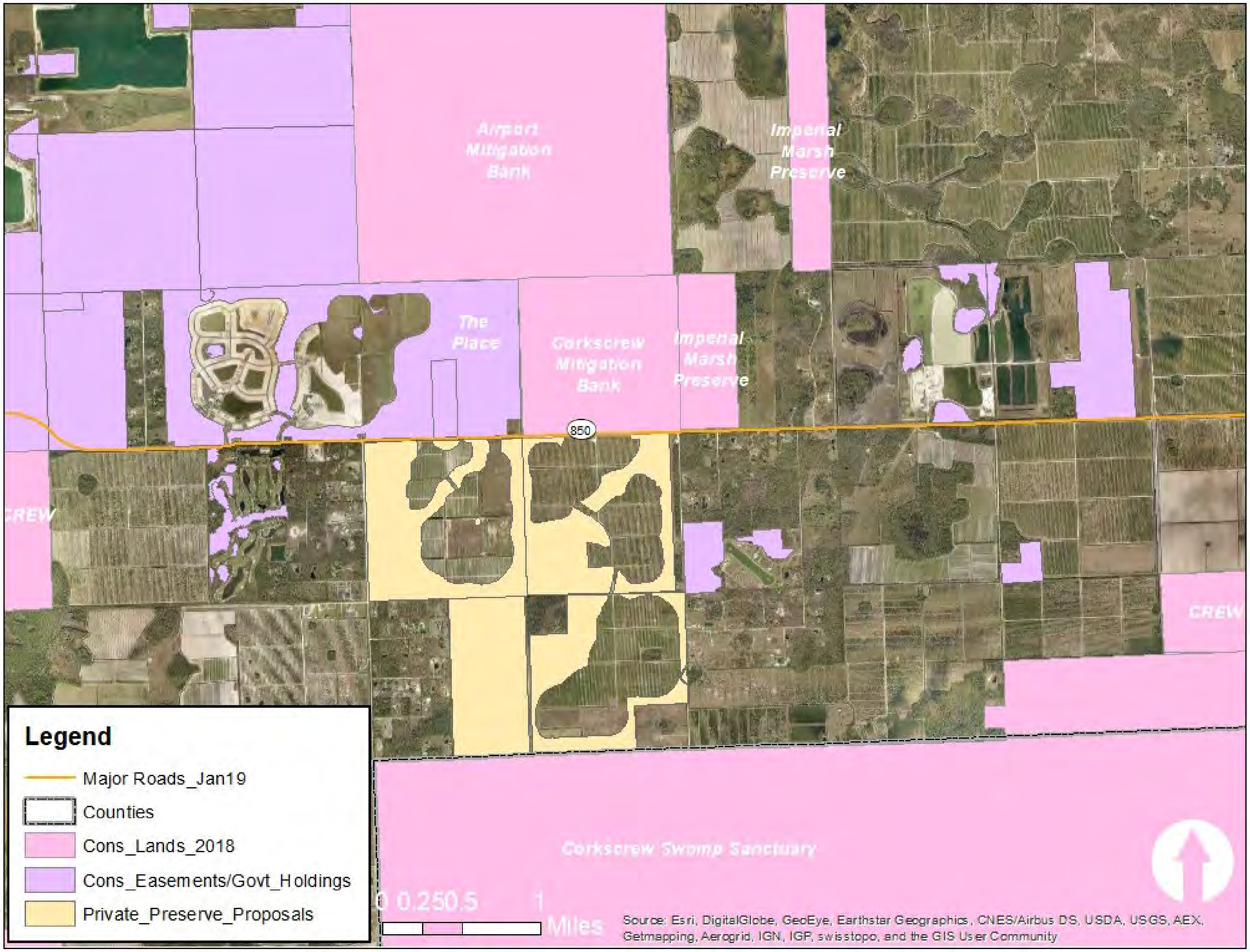

Figure 5. Public and private conservation lands along the east-west segment of Corkscrew Road. Included among the areas highlighted are conservation easements created as part of development and mining permits. Other local government land holdings are also shown. Noteworthy, is a network of conservation linkages (in yellow) planned as part of two development proposals that would connect the conservation areas north of Corkscrew Road to the Corkscrew Swamp Sanctuary to the south.

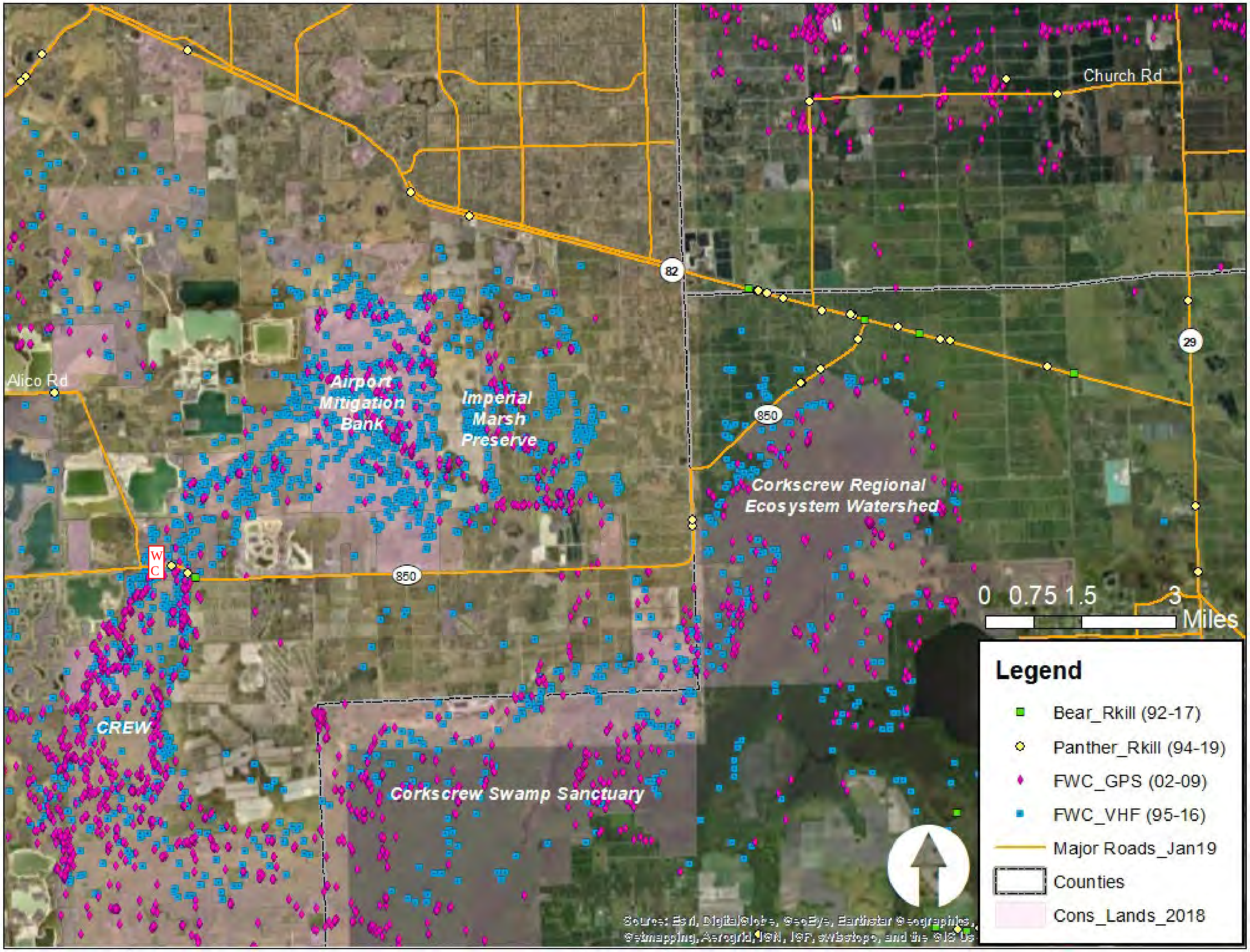

Figure 6. Telemetry concentrations and road mortalities of Florida panthers within the Corkscrew Regional Ecosystem Watershed (panther and bear location data provided by FWC). Constructed wildlife crossings are designated by WC.

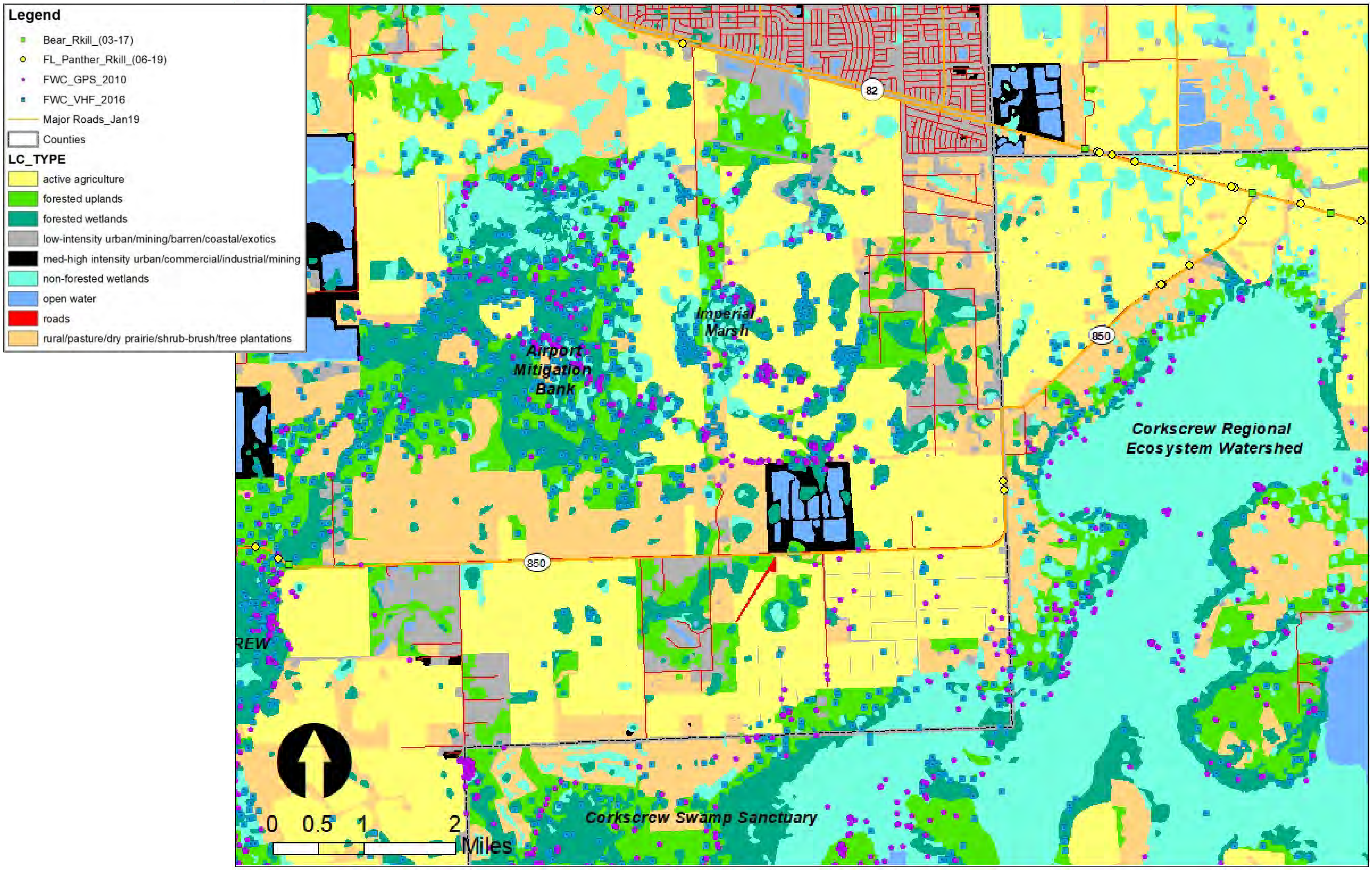

Figure 7. Land cover for the Corkscrew Road study area (data: FWC 2018). For display purposes, land cover was condensed into 9 basic categories. Panther telemetry and roadkill locations are overlaid to illustrate relative use of different habitat types.

METHODS

Field Activities:

We used camera trap arrays to capture panther activity along Keri and Corkscrew Roads in the general study areas (see figs. 1 and 4). To identify candidate monitoring locations for the cameras we used two methods, GIS analysis and field reconnaissance.

First, we created overlays of panther roadkill and telemetry locations, conservation lands and easements and land cover (focused primarily on preferred land cover types by panthers). From this data we identified generalized road segments where panthers either already cross or most likely would cross over the road. Figures 8 and 9 display the locations of initial road segments identified for placement of camera trap arrays.

Second, we performed field surveys of each of these road segments by either driving < 5 mph or walking along the road shoulders to identify and record the location of any large animal trails through the tall grass and roadside brush. In many cases there were existing recreational trails, maintenance roads and firebreaks associated with potential road crossing sites. Side access roads also provided select opportunities for animals to easily and safely cross over roadside drainage channels and swales.

A thorough evaluation was performed at each road segment to identify the location and number of wildlife movement pathways leading to/from the road. This was necessary to determine number of cameras required and optimum camera placement. The number of cameras needed to adequately monitor each road segment varied from 1 to 7 (Table 1). Appendices A and B include a set of maps of each camera array showing placement location and arrows indicating pathways or trails adjacent to Keri and Corkscrew roads, respectively. Appendices C and D include site photographs of each monitoring location showing the general character of the vegetation present and notable landscape features (e.g., animal trails, public access roads/trails).

Cameras were mounted on trees and fence posts and optimally fixed at an angle to capture panthers at the targeted location on trails, firebreaks, access roads, etc. (fig. 10). Cameras were set to take either a 3-image burst or 30 sec video and recorded 24 hrs/day. Cameras were operated from December 2017 to May 2019 to capture seasonal variation in wildlife activity. We checked cameras once every 2 months to collect data, check batteries and camera settings, and perform site maintenance as needed (i.e., prevent encroaching vegetation from causing false triggers). Camera placement at each site was adjusted to improve capture effectiveness and minimize disturbance, if necessary following review of the first period of collected images.

Data Management and Analysis:

Supervised volunteers sorted images from each recording interval into separate folders based on species. Separate events were recorded into a master spreadsheet and were coded by site number, camera number, date, image number, time, species, the direction of travel, the number of photos associated with the event, and the number of individuals present.

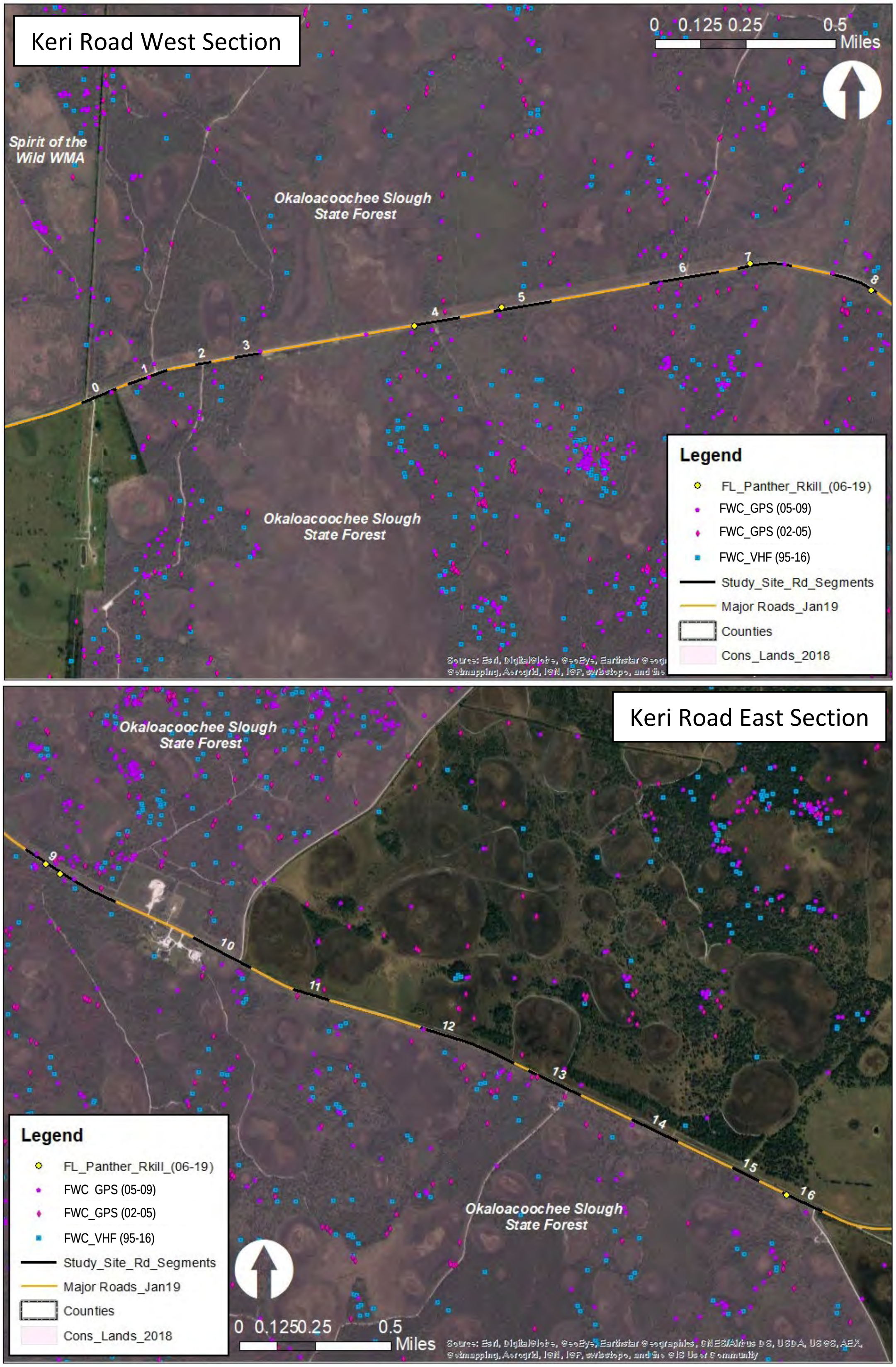

Figure 8. Selected road segments for deploying camera trap arrays to monitor panther activity along the Keri Road (OKSSF/SW) study area.

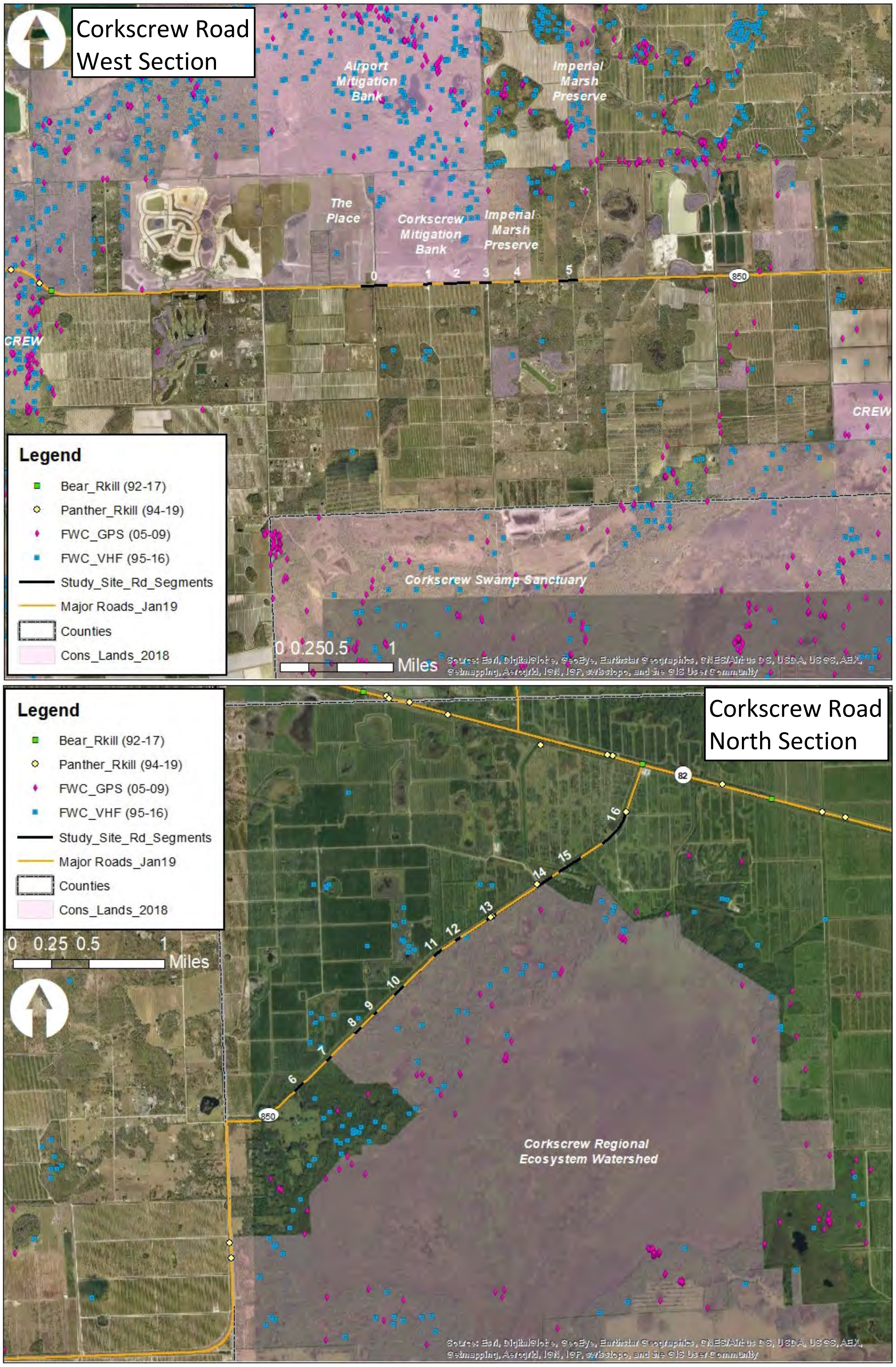

Figure 9. Selected road segments for deploying camera trap arrays to monitor panther activity along the Corkscrew Road study area.

Figure 10. Typical post mounting of trail camera along an animal trail.

Table 1. Number of cameras deployed to monitor each road segment.

Study Area	Location	Road Segment	# of Cameras
Keri Rd West	OK Slough SF	0	4
Keri Rd West	OK Slough SF	1	6
Keri Rd West	OK Slough SF	2	5
Keri Rd West	OK Slough SF	3	7
Keri Rd West	OK Slough SF	4	7
Keri Rd West	OK Slough SF	5	2
Keri Rd West	OK Slough SF	6	6
Keri Rd East	OK Slough SF	9	4
Keri Rd East	OK Slough SF	10	7
Keri Rd East	Alico Ranch	12	3
Keri Rd East	Alico Ranch/OKSSF	13	3
Keri Rd East	Alico Ranch	14	2
Keri Rd East	Alico Ranch	15	1
Keri Rd East	Alico Ranch/OKSSF	16	4
Corkscrew Rd West	The Place/CMB	0	5
Corkscrew Rd West	Corkscrew Mitigation Bank	1	1
Corkscrew Rd West	CMB	2	4
Corkscrew Rd West	CMB/IMP	3	6
Corkscrew Rd West	Imperial Marsh Preserve	4	3
Corkscrew Rd North	Alico Groves	6	1
Corkscrew Rd North	Alico/CREW	7	2
Corkscrew Rd North	CREW	8	1
Corkscrew Rd North	CREW	9	1
Corkscrew Rd North	Alico/CREW	10	3
Corkscrew Rd North	Alico Groves	11	2
Corkscrew Rd North	CREW	12	1
Corkscrew Rd North	CREW	14	4
Corkscrew Rd North	Powerlines	15	2
Corkscrew Rd North	Alico/CREW	16	2

An event was defined as an isolated occurrence of a species (including presence of 1 or more individuals at the same time interval). A new event was recorded if a new species appeared or more than 5 minutes had elapsed since the species was last seen. Entries from volunteers were spot checked for errors. Each data collection period (approx. 2 mos.) was recorded into a master spreadsheet. The master spreadsheet described the number of photos taken in that period, significant notes, and the date the photos were input into the master spreadsheet. Any malfunctions or gaps in camera operation were recorded to calculate the number of active recording days.

We also recorded vehicles and people (hikers, bikers, hunters, maintenance workers, etc.) that were caught on camera at each respective site. Their effect on presence/abundance of wildlife at each location was evaluated. In addition, we collected rainfall and temperature data to evaluate potential seasonal effects on presence/abundance at each study location (e.g., wet season access to some sites was limited).

The repeated count data (i.e., number of events per species) were summed for each site and month of observation for the time period spanning December 2017- May 2019. The event count data (for target species: FL panther, black bear, bobcat, and whitetail deer) were then assessed in R (R Core Team, 2013) by fitting an N- mixture model (Royle 2004) using the package “unmarked” (Fiske 2011) which fits hierarchical models to models of measures of wildlife occurrence and abundance. The number of active camera days at each site was used as a covariate of the **detection process** given that a site with more camera days is more likely to have more wildlife events.

Eight possible covariates were examined in relation to the **state process** of species occurrence or abundance (Table 2). Four of the covariates were categorical: presence of access road (y/n), presence of adjacent canal (y/n), FWC 2018 land cover (represented by type with greatest areal extent at 0.2 ha surrounding the centroid of each study site: *citrus*, *improved pasture*, *marsh impoundments*, *mesic flatwoods*, *oak and cabbage palm forest*, *shrub and brush*), and native shrub and tall grass cover (<1/3, 1/3-2/3, >2/3). The remaining four covariates were continuous: foot/bicycle traffic, percent tree cover, clear zone width (m), and distance from camera site cluster to road centerline (m). It is important to note that for statistical purposes an “access road” only includes highly maintained, unpaved roads for land management and/or recreation/hiking. It does not include firebreaks, unmaintained hunting paths or animal trails.

First, we generated a correlations matrix between abundance covariates in the Keri Road and Corkscrew Road study areas to prevent significantly correlated variables from being included in the same model. Second, each state process covariate was separately entered in the N- mixture model with active camera days as the detection process covariate. Third, for each significant correlation between covariates we retained only the more informative covariate as measured by minimum AIC in the previous step. AIC is a measure of model quality that balances model simplicity with goodness-of-fit in order to compare competing models during model selection (Akaike 1974). This resulted in 4 independent covariates on abundance for each species in each study area. Fourth, all possible combinations of the selected state process covariates were evaluated, and the top model was selected by minimum AIC. Active camera days was used as a covariate in the detection process in all models.

Lastly, we calculated the Bayesian best estimated, unbiased predictors of the mean posterior abundance distribution to select the sites with the highest relative abundance (or occurrence) for the target species in each study area. Crucially, these are not ***actual*** abundance estimates, but rather estimates relative to the distribution of abundance (occurrences) across sites (Royle 2004).

Table 2. Site cluster parameters (covariables) used in R for analysis of relative abundance or occurrence of target species.

Study area	Area divisions	Site cluster (rd segment)	Foot/ bicycle traffic	Med distance-site cluster to rd centerline (m)	Clear zone width (m)	Avg % tree cover (at 0.2 ha)	Shrub/ tall grass cover	Adj canal	Access rd/ rec trail	FWC 2018 land cover (primary)
Keri Road	W	S0	70	64.5	68	95	> 2/3	n	y	shrub & brush
Keri Road	W	S1	47	23	31	57	1/3 to 2/3	n	y	mesic flatwoods
Keri Road	W	S2	74	32	53	30	1/3 to 2/3	n	y	mesic flatwoods
Keri Road	W	S3	7	46.5	50	45	1/3 to 2/3	n	n	mesic flatwoods
Keri Road	W	S4	156	45	49.5	43	1/3 to 2/3	n	y	mesic flatwoods
Keri Road	W	S5	6	54	62	50	1/3 to 2/3	y	n	mesic flatwoods
Keri Road	W	S6	34	34	48.5	33	1/3 to 2/3	y	y	mesic flatwoods
Keri Road	E	S9	59	53.5	63.5	50	1/3 to 2/3	n	y	mesic flatwoods
Keri Road	E	S10	42	54	92	10	< 1/3	y	y	improved pasture
Keri Road	E	S12	24	62	77	33	< 1/3	y	n	oak-cabbage palm forest
Keri Road	E	S13	18	70	67	33	1/3 to 2/3	n	y	mesic flatwoods
Keri Road	E	S14	35	52.5	65.5	50	< 1/3	y	y	oak-cabbage palm forest
Keri Road	E	S15	3	63	64	30	< 1/3	y	n	oak-cabbage palm forest
Keri Road	E	S16	24	49	97	25	< 1/3	n	y	improved pasture
Corkscrew Rd	W	S0	56	21	40.5	12	< 1/3	n	y	shrub & brush
Corkscrew Rd	W	S1	100	109	37	15	< 1/3	n	y	marsh impoundments
Corkscrew Rd	W	S2	95	18.5	30	23	< 1/3	y	y	marsh impoundments
Corkscrew Rd	W	S3	52	16	55	13	1/3 to 2/3	n	n	marsh impoundments
Corkscrew Rd	W	S4	25	16	32.5	20	1/3 to 2/3	n	y	marsh impoundments
Corkscrew Rd	N	S6	6	25	28	15	1/3 to 2/3	y	n	shrub & brush
Corkscrew Rd	N	S7	23	25	26.5	25	1/3 to 2/3	y	n	mesic flatwoods
Corkscrew Rd	N	S8	24	70	39	75	1/3 to 2/3	n	y	mesic flatwoods
Corkscrew Rd	N	S9	16	14	32	50	1/3 to 2/3	y	n	mesic flatwoods
Corkscrew Rd	N	S10	98	123	27	54	1/3 to 2/3	y	y	mesic flatwoods
Corkscrew Rd	N	S11	0	32.5	43	5	1/3 to 2/3	n	y	citrus
Corkscrew Rd	N	S12	29	14	39	50	1/3 to 2/3	y	n	mesic flatwoods
Corkscrew Rd	N	S14	52	14	51.5	49	1/3 to 2/3	n	n	mesic flatwoods
Corkscrew Rd	N	S15	8	74.5	25	43	1/3 to 2/3	n	y	shrub & brush
Corkscrew Rd	N	S16	7	173	45	5	< 1/3	n	y	citrus

Note: FWC 2018 land cover (primary) is represented by type with greatest areal extent at 0.2 ha surrounding the centroid of each study site.

KERI ROAD STUDY AREA
RESULTS

Cameras were first deployed at the Keri Road study area in late December of 2017. We installed a total of 61 cameras; as a result not all cameras have the same start date. We had three separate installation periods; the last ones were installed in early June 2018. All cameras were operational for approximately 12 months, the field work ending in May of 2019. Due to the practical lag in installation, periodic camera malfunctions and obstructions, the number of active camera-trap days varies by site (Table 3). Number of active camera-trap days by site also differs due to the range in number of cameras deployed at each site (see Tables 1 and 3). These differences were addressed in our statistical evaluation.

We recorded a total of 4,428 events of the target species (Table 3). Of greatest importance are recorded events of FL panthers (n=454) and their primary prey species, white-tailed deer (n=3,397). It is important to note that number of events does not equate to number of individuals. We were unable to identify individuals from photographs. The same individuals likely passed by our cameras numerous times. Other carnivores were also commonly captured in photo events at many of the monitoring sites.

Table 3. Active camera-trap days by site and no. of events of target species at Keri Road study area (see fig. 8 for location of study sites).

Study area	Study site/ road segments	Active camera-trap days	All target species	FL panther	Black bear	Bobcat	Whitetail deer
Ok Slough West	0	1340	312	32	7	19	254
Ok Slough West	1	2148	601	98	15	133	355
Ok Slough West	2	1073	289	13	3	26	247
Ok Slough West	3	2281	969	76	17	41	835
Ok Slough West	4	1058	407	41	6	92	268
Ok Slough West	5	659	82	9	0	5	68
Ok Slough West	6	1732	220	12	1	34	173
Ok Slough East	9	1306	400	100	3	67	230
Ok Slough East	10	1160	439	15	3	15	406
Ok Slough East	12	1241	150	0	1	3	146
Ok Slough East	13	1064	265	23	0	33	209
Ok Slough East	14	699	110	13	1	25	71
Ok Slough East	15	361	54	3	0	1	50
Ok Slough East	16	1207	130	19	1	25	85
	Total	**17,329**	**4,428**	**454**	**58**	**519**	**3,397**

Bayesian best estimated unbiased predictors:

The sites at which each species were most abundant as measured by Bayesian posterior abundance estimates differed; abundance estimates for FL panthers and bobcats were highest in road segments 1, 4 and 9, black bear abundance was greatest in road segments 0, 1 and 4, while estimates for whitetail deer were highest in road segments 2, 3, and 10 (Table 4).

Site	FL panther	Bobcat	Black bear	Whitetail deer
0	31.1064	28.88032	**75.79603**	218.6925
1	**39.0432**	**61.15806**	**75.10112**	186.6995
2	24.2726	37.93273	71.64468	**238.7565**
3	28.4685	23.46258	72.74194	**294.9384**
4	**38.9179**	**73.22854**	**76.16035**	237.9384
5	26.6269	28.07290	0	149.5642
6	12.8192	31.62239	66.91673	128.7061
9	**61.4989**	**55.28872**	72.12760	211.9376
10	24.2132	29.11051	72.90366	**291.3085**
12	0	18.75602	71.36577	181.2960
13	31.1773	42.48192	0	207.4662
14	28.8274	42.49709	72.28596	157.6564
15	24.3964	27.33735	0	159.4151
16	24.2822	32.77472	70.68868	133.6254

Table 4: Posterior abundance estimates for target species at each site on Keri Road as measured by Bayesian best unbiased predictors. The three highest abundance estimates for each species are shown in bold type.

Correlation between covariates:

Several significant correlations between covariates were found in OKSSF (Table 5). In each case where a significant correlation was found, the more informative covariate was selected for each species in each study area (Table 6).

Table 5: Correlations matrix for covariates in the Keri Road study area.

	Adjacent canal	Access road	Rd centerline to site cluster	Clear zone width	Foot/ bicycle traffic	FWC land cover type	Shrub and tall grass cover	% Tree cover
Adjacent canal	-	0.1243	0.4838	0.3984	0.0596	0.12	0.0998	0.2408
Access road	-	-	0.2929	0.9817	0.0247	0.3362	0.6805	0.8027
Rd centerline to site cluster	-	-	-	0.0237	0.341	0.2991	0.1832	0.817
Clear zone width	-	-	-	-	0.9617	0.0029	0.0145	0.1851
Foot/bicycle traffic	-	-	-	-	-	0.6108	0.8145	0.7534
FWC land cover type	-	-	-	-	-	-	<0.0001	0.0008
Shrub and tall grass cover	-	-	-	-	-	-	-	0.0012
% Tree cover	-	-	-	-	-	-	-	-

Note: Significant correlations are shown in red.

Table 6: AIC values for species abundance models in the Keri Road study area using a single covariate in the state process.

Covariate	FL panther	Bobcat	Black bear	Whitetail deer
Adjacent canal	979.4136	1304.493	242.9161	5630.433
Access road	*1012.649*	1283.47	*248.748*	5608.225
Centerline to site cluster	*1016.302*	*1321.613*	*250.2442*	5656.967
Clear zone width	1013.432	1302.182	249.0446	*5656.475*
Foot/bicycle traffic	1008.544	*1284.908*	241.4173	*5627.019*
FWC land cover type	*1006.689*	*1309.591*	*249.9742*	5616.02
Shrub and tall grass cover	*1005.941*	*1353.34*	*248.4157*	*5649.581*
Percent tree cover	979.4136	1304.493	245.1075	*5656.816*

Note: Covariates eliminated from further consideration are shown in gray italics.
Covariates included in the final models for each species were identified by selecting for the lowest AIC score (above) in highly correlated pairs (see Table 5).

Species relative abundance models:

Abundance models containing only the covariate of active camera days showed significant effects on the detection process (FL panther, p=5.65e-17; bobcat, p=6.62e-15; black bear, p=1.14e-09; and whitetail deer, p=2.1e-108). Shapiro-Wilk normality tests indicated the distribution of events for each species was not normal (panther, p=0.0027; bobcat, p=0.0095; bear, p=0.0004; deer, p=0.0034), therefore the nonparametric Wilcoxon analysis was used in categorical comparisons.

The best-fitting FL panther model (Active camera days ~ Adjacent canal + Clear zone width + Percent tree cover; AIC = 976.3906) indicated abundance was significantly higher in segments without adjacent canals (Wilcoxon, p=0.0045). Panther abundance also had a significant positive correlation with percent tree cover (p=0.0325, R^2=0.352) and an insignificant negative correlation with clear zone width (p=0.0741, R^2=0.242). Results from all panther models are listed in Table 7.

The best-fitting bobcat model (Active camera days ~ Adjacent canal + Access road + Clear zone width + Percent tree cover; AIC = 1226.849) indicated that bobcat abundance was significantly higher in road segments without adjacent canals (Wilcoxon, p=0.0239). Abundance was higher (but insignificantly) in segments with an access road present (p=0.1247, R^2=0.1851). Bobcat abundance was significantly negatively correlated with clear zone width (p=0.0117, R^2=0.4235) and significantly positively correlated with percent tree cover (p=0.0449, R^2=0.3175). Results from all bobcat models are listed in Table 8.

The best-fitting black bear model (Active camera days ~ Foot/bicycle traffic + Percent tree cover; AIC = 239.772) indicated bear abundance was positively correlated with foot/bicycle traffic (p=0.7654, R^2=0.0071) and percent tree cover (p=0.1231, R^2=0.1297) but both of these relationships were insignificant. Results from all bear models are listed in Table 9.

Table 7: AIC (of best-fitting model) and Δ AIC (from best-fitting model) for all 15 considered FL panther abundance models in the Keri Road Study area.

Covariate combinations	Δ AIC from best-fitting model	AIC
Adj canal + Clear zone + Percent tree cover	0	976.3906
Adj canal + Clear zone	0.4806	976.8712
Adj canal + Percent tree cover	1.5735	977.9641
Adj canal + Clear zone + Foot traffic + Percent tree cover	1.9194	978.31
Adj canal + Clear zone + Foot traffic	2.4116	978.8022
Adj canal	3.023	979.4136
Adj canal + Foot traffic + Percent tree cover	3.5755	979.9661
Adj canal + Foot traffic	5.0252	981.4158
Foot traffic + Percent tree cover	24.5044	1000.895
Clear zone + Foot traffic + Percent tree cover	24.9584	1001.349
Percent tree cover	29.5504	1005.941
Clear zone + Percent tree cover	29.9014	1006.292
Clear zone + Foot traffic	30.7824	1007.173
Foot traffic	32.1534	1008.544
Clear zone	37.0414	1013.432

Table 8: AIC (of best-fitting model) and Δ AIC (from best-fitting model) for all 15 considered bobcat abundance models in the Keri Road Study area.

Covariate combinations	Δ AIC from best-fitting model	AIC
Adj canal + Access Rd + Clear zone + Percent tree cover	0	1226.849
Adj canal + Access Rd + Clear zone	0.566	1227.415
Access Rd + Clear zone	17.949	1244.798
Access Rd + Clear zone + Percent tree cover	19.933	1246.782
Adj canal + Access Rd	32.059	1258.908
Adj canal+ Access Rd + Percent tree cover	33.816	1260.665
Adj canal + Clear zone	34.7	1261.549
Adj canal + Clear zone + Percent tree cover	35.645	1262.494
Access Rd	56.621	1283.47
Access Rd + Percent tree cover	56.925	1283.774
Clear zone	75.333	1302.182
Clear zone + Percent tree cover	76.739	1303.588
Adj canal	77.644	1304.493
Adj canal + Percent tree cover	79.615	1306.464
Percent tree cover	126.491	1353.34

Table 9: AIC (of best-fitting model) and Δ AIC (from best-fitting model) for all 15 considered black bear abundance models in the Keri Road Study area.

Covariate combinations	Δ AIC from best-fitting model	AIC
Foot traffic + Percent tree cover	0	239.772
Adj canal + Foot traffic + Percent tree cover	1.3864	241.158
Adj canal + Foot traffic	1.4712	241.243
Foot traffic	1.6456	241.417
Clear zone + Foot traffic + Percent tree cover	2.0181	241.79
Adj canal	3.1444	242.916
Adj canal + Clear zone + Foot traffic + Percent tree cover	3.1929	242.965
Adj canal + Percent tree cover	3.2529	243.025
Clear zone + Foot traffic	3.451	243.223
Adj canal + Clear zone + Foot traffic	3.57	243.342
Adj canal + Clear zone	4.016	243.788
Adj canal + Clear zone + Percent tree cover	4.2936	244.065
Percent tree cover	5.3358	245.108
Clear zone + Percent tree cover	6.5403	246.312
Clear zone	9.2729	249.045

The best-fitting whitetail deer model (Active camera days ~ Access road + FWC land cover type; AIC = 5598.293) indicated abundance was higher in segments without access roads, but this relationship was not significant (Wilcoxon, p=0.358). Deer abundance, in association with FWC land cover type, was greater in segments dominated by *mesic flatwoods* than in segments dominated by *oak-cabbage palm forest*, but this relationship was not significant (Wilcoxon, p=0.2467). Results from all deer models are listed in Table 10.

Other effects:

We collected rainfall and temperature data from the nearest station in LaBelle, FL for the study period December 2017 to May 2019 (fig. 11). There was a peak in rainfall from May to August of 2018. This resulted in flooding of all sites within or near marsh areas, making these locations somewhat inaccessible. This also resulted in elevated water levels in roadside channels and swales increasing the barrier effects of the road to terrestrial wildlife movement.

Another factor potentially affecting movement by panthers and other wildlife was presence of vehicles. We compared number of photo events of vehicles to photo events of panthers at all camera sites monitoring access roads to the state forest (Table 11). Number of panthers was greatest at site 9, where the gate was kept closed to vehicles during most of the study period. To the contrary, site 1 had the second highest volume of panther use, but 4 times the vehicles as site 9.

Table 10: AIC (of best-fitting model) and ∆ AIC (from best-fitting model) for all 15 considered whitetail deer abundance models in the Keri Road Study area.

Covariate combinations	∆ AIC from best-fitting model	AIC
Access Rd + FWC	0	5598.293
Access Rd + Centerline + FWC	0.74	5599.033
Adj canal + Access Rd + Centerline + FWC	2.107	5600.4
Adj canal + Access Rd + Centerline	6.108	5604.401
Adj canal + Access Rd	6.692	5604.985
Access Rd + Centerline	8.137	5606.43
Access Rd	9.932	5608.225
Adj canal + FWC	13.522	5611.815
Adj canal + Centerline + FWC	15.32	5613.613
FWC	17.727	5616.02
Centerline + FWC	19.38	5617.673
Adj canal + Access Rd + FWC	22.613	5620.906
Adj canal	32.14	5630.433
Adj canal + Centerline	33.227	5631.52
Centerline	58.674	5656.967

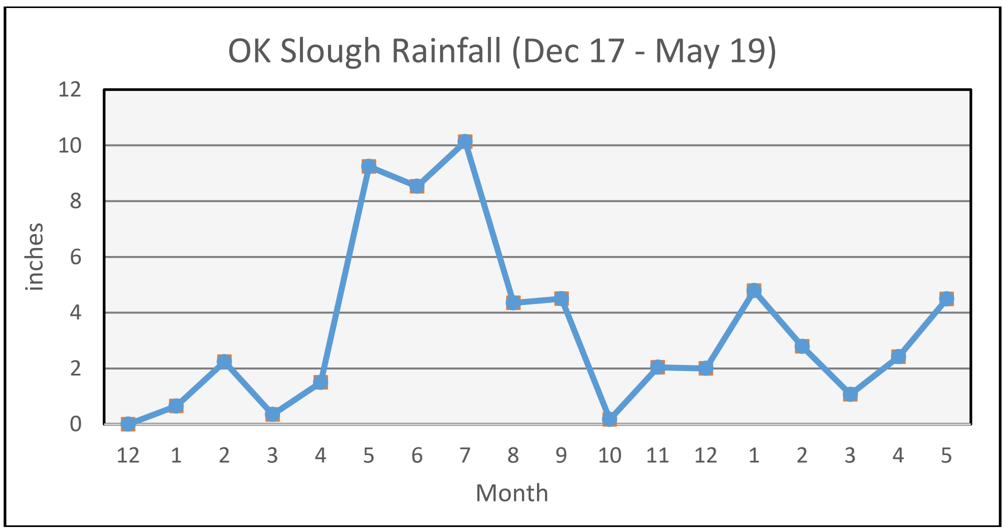

Figure 11. Approximate rainfall amounts for the Keri Road study area (LaBelle, FL data from: NOAA 2019).

We also examined the effect of season on the number of events recorded for each species group. Based on the data collected, we defined species groups as carnivores (black bear, bobcat, coyote, river otter), ungulates (white-tailed deer, wild hog), meso-mammals (Virginia opossum, raccoon, nine-banded armadillo), small mammals (rabbits), and avian (wild turkey and sandhill crane). Panthers were evaluated separately. Sites west of the Ok Slough are shown in fig. 12 (and in tabular form in Appendix E), and sites east of the OK Slough are shown in fig. 13 (and in tabular form in Appendix E). The OK Slough forms a natural barrier to terrestrial wildlife movement between the two areas and is an appropriate physical feature to subdivide the dataset for presentation purposes.

Table 11. Comparison of # of panther events and # of vehicles at key drainage channel crossover sites.

Site	Camera	Road/Trail	# of vehicles	# of panthers	panthers/vehicle
0	1	Boundary Trail	191	20	0.105
1	4	North Loop Rd - west	1168	39	0.033
2	5	Sic Island Rd	2219	17	0.008
4	7	Dog Island trailhead	829	2	0.002
6	1	Oil Pad Rd	440	4	0.009
9	4	Keri Tower Rd	277	65	0.235
10	7	Twin Mills Grade	4599	13	0.003
13	1	Patterson Rd	490	23	0.047
16	3	Wild Cow Grade	5605	22	0.004

Note: Yellow highlights indicate where gates were kept locked, only public access on foot was allowed. All other sites were open to vehicles except during flooded periods to prevent erosion.

In the Keri Road West study area, panthers were most commonly recorded at sites S0/S1, S3 and S4, in that order (fig. 12). The Fall season exhibited the greatest activity, and the summer period when flood levels were greatest didn’t appear to have a significant impact. For other carnivores, sites S0/S1 and S4 had the greatest use. In this case the greatest activity occurred in Fall and Summer. Ungulates included only deer in OK Slough West; they were more frequently captured on camera than any other species. Sites S0/S1 and S3 had the highest numbers, but they were also common at S2 and S4. They were most frequently recorded in Summer, but also common in Spring and Fall. Avian events (mostly turkey) by site were highest at S4 across all seasons. At site S4 in spring we recorded 51 events of sandhill crane, and 33 events of American alligator were recorded at S2 in fall and winter. Event records were lower for all species groups at site S5; this site was adjacent to slough marsh on the south side of the road, did not include dry access over the roadside channel and the shrub vegetation growing in the canal was dense.

In the Keri Road East study area, only site S9 exhibited frequent use by panthers, all sites except S12 were occasionally used (fig. 13). No panthers were recorded at site S12. Spring and Fall seasons had the greatest activity. With other carnivores, few bears or coyotes were recorded. Bobcats were common in this area, especially at S9, S13, S14 and S16. Bobcat activity was most recurrent in Winter and Spring. Ungulates included only deer in OK Slough East; there were about half as many as recorded in OK Slough West. Sites S10, S9, S13 and S12 had the highest numbers, in that order. They were most frequently recorded in Spring and Summer. Avian events (mostly turkey) were highest at sites S9, S10 and S12. Spring and Summer had the highest number of Avian events.

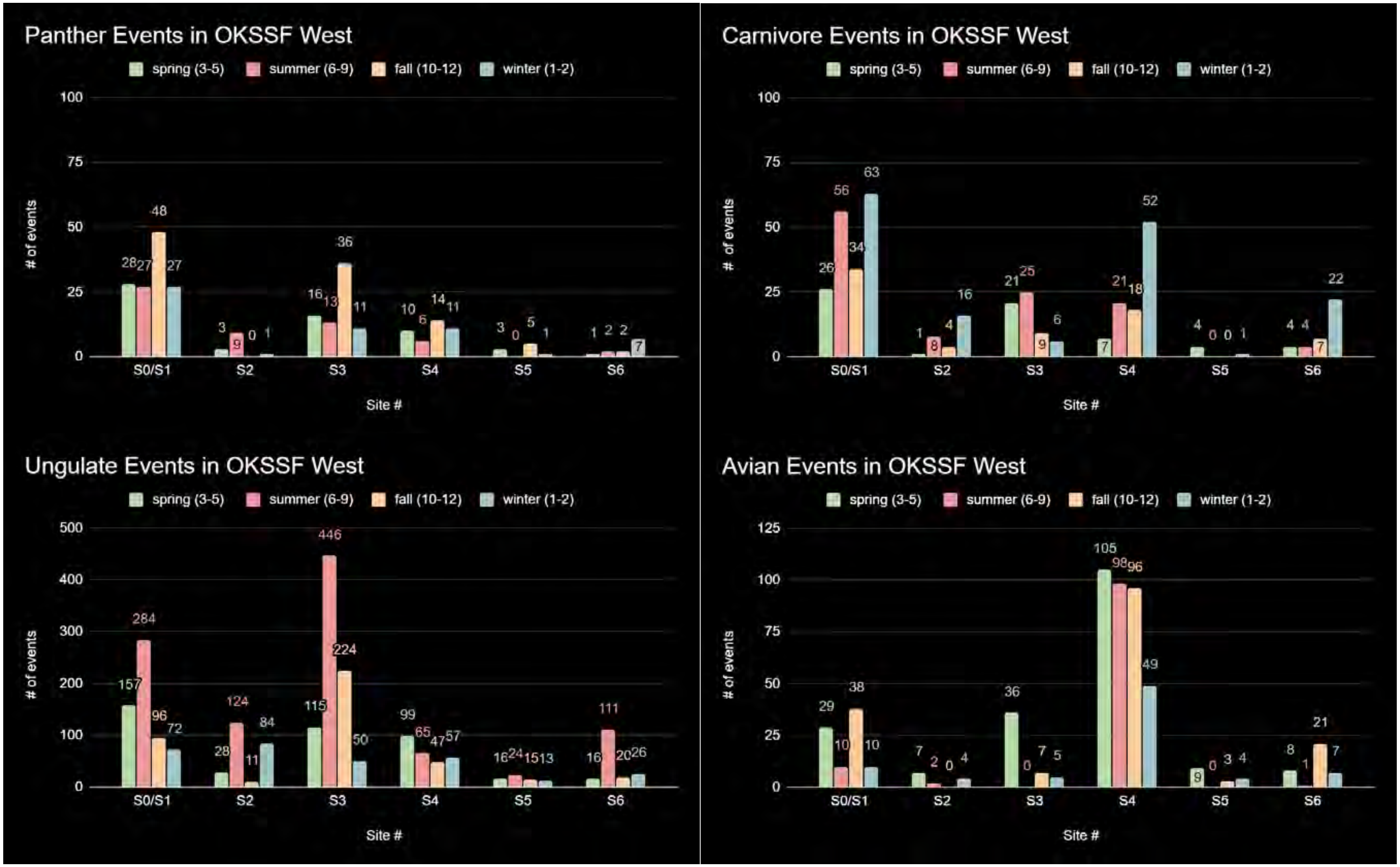

Figure 12. Number of photo events by season by species for monitoring sites in OK Slough West (see fig. 8 for site locations). For meso- and small- mammal event records, see Appendix E.

Figure 13. Number of photo events by season by species for OK Slough East (see fig. 8 for site locations). For meso- and small-mammal event records, see Appendix E.

KERI ROAD STUDY AREA
DISCUSSION

Field surveys on Keri Road were confounded by a parallel roadside drainage channel on the southside of the road. The channel averaged about 20-25 ft wide and was covered almost entirely by entangled, dense shrubby vegetation. This made it quite difficult to discern many possible crossing points by wildlife on the south side of the road. We suspect this also created a significant challenge to any wildlife attempting to cross it. We monitored 6 sites where the drainage channel was a potential barrier, 7 sites where the drainage channel was bridged by an access road or trail and 2 sites (S1, S3) where there wasn't a bridge over the channel, but sediment accumulation made it possible to cross, particularly during the dry season.

Our findings for the OK Slough area identified sites S9, S1 and S4 on Keri Road as the most critical sites for panther activity (see Table 4). Important secondary sites included S0, S3, S10 and S13 (S3 and S10 also ranked high for deer occupancy). These findings match the density/patterns of composite panther telemetry locations and panther-vehicle collision sites (see fig. 8). As such, road crossings may be common at several locations. Schwab and Zandbergen (2011) would describe Keri Road as a "minor road", in that current road size and traffic level does not cause significant avoidance by panthers. Crossing avoidance behavior and collision risk would be expected to increase with increased traffic.

Of note, site S6 scored lower than expected, possibly due to the absence of a land crossing of the drainage channel on the southside of the road. Suitable habitat exists on both sides of the road at this site, so installing a culvert and land-crossing over the drainage channel might increase use at this location. All 7 sites listed above of primary or secondary importance for panther activity include *existing* land crossings of the drainage channel on the southside of the road. This likely influenced greater presence by panthers and other wildlife intent on crossing the Keri Road.

Keri Road at present has only 450 vehicles/day. Instead of high volume, high-speed and driver visibility are the likely causes of collisions with wildlife. Collision risk is greatest in sections of the road where driver visibility is reduced either from severe curves or dense vegetation near the road. Because of these conditions, the least expensive remedy would be posted speed reductions and increased enforcement. Speed-triggered wildlife warning lights may increase driver awareness and use of animal detection/warning systems might be considered at several locations.

We identified several road crossing locations used by wildlife, facilitated by access roads and trails that allow wildlife to cross the deep-water channel along the southside of the road. As such, crossing opportunities are many and it would be challenging economically to address entirely with wildlife crossing structures and fencing. Below we provide recommendations based on greatest need, but we also include elements that greatly would reduce the impact of Keri Road on the adjacent ecosystem (e.g., flow-ways of OK Slough are essentially dammed by the roadway).

<u>Keri Road West, Road Crossing Patterns and Recommendations:</u>

The Keri Road west study area includes 3 physically separated site (road segment) clusters that exhibit inter-related road crossing patterns, sites 0-3, 4-5, and 6-7 (fig. 8). At the western property boundary of OK Slough SF, we identified interactions between sites 0 and 1, sites 1 and 2, and sites 2 and 3 (Appendix A). The inter-related use of these sites was facilitated by firebreaks parallel to and on each side of the road that provided pathways for panthers and other wildlife. Through analysis and observation, we identified 3 wildlife crossing points: the first two where North Loop Road and Sic Island Road each intersect with Keri Road and the third where a pathway and sediment-filled section of the roadside ditch exists at road segment 3 (fig. 14). Road segment 1 was one of the top three most important sites for panthers identified in our analysis, and road segments 0 and 3 were high ranking secondary locations.

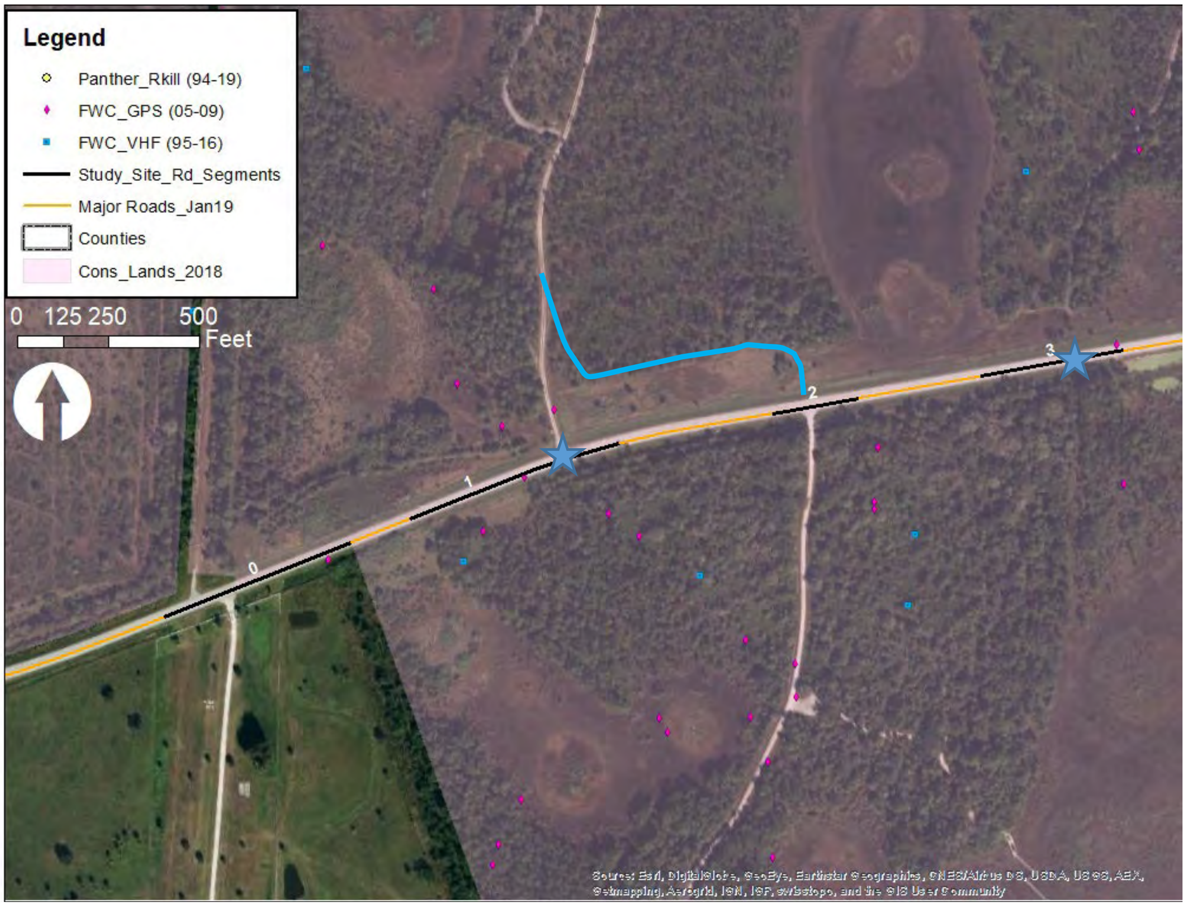

Figure 14. Identified wildlife crossing points at road segments 0-3 in OK Slough SF. Blue highlighted stars indicate proposed locations for wildlife crossing structures and rerouted access for North Loop Road. Accompanying wildlife fencing would be needed through this section. (**Important note:** These recommendations apply if/when traffic increases and panther-vehicle collision risk increases).

On this low-traffic volume road, we would recommend wildlife crossing structures similar in width and height to that installed at Camp Keias Strand on Immokalee Road (e.g., 6 ft high by 12 ft wide). In fig. 14 we show the relocation of the intersection of North Loop Road with Keri Road. This is necessary to provide enough distance to raise the roadbed for the crossing structure. The recommendation for crossing structures is associated with the importance of this site as a crossing location for panthers, however it is important to note that no panther-vehicle collisions have been recorded at this location to date. Because of this the ***urgency*** to install crossings may not be that high at present. However, it will be important to monitor this location should conditions change and increase the need (urgency) to address wildlife-vehicle conflicts through the mitigation measures recommended.

Road segments 4 and 5 form the next site cluster where common road crossing patterns by wildlife were identified (fig. 15). Site no. 4 was among the top three ranked sites identified in our analysis. Most crossing activity occurs across from Dog Island parking area at site no. 4, but one panther roadkill and telemetry points indicate that some road crossing activity by panthers may also occur at the west extent of road segment 5 (see also Appendix A). A second panther-vehicle collision occurred at the westernmost end of road segment 4.

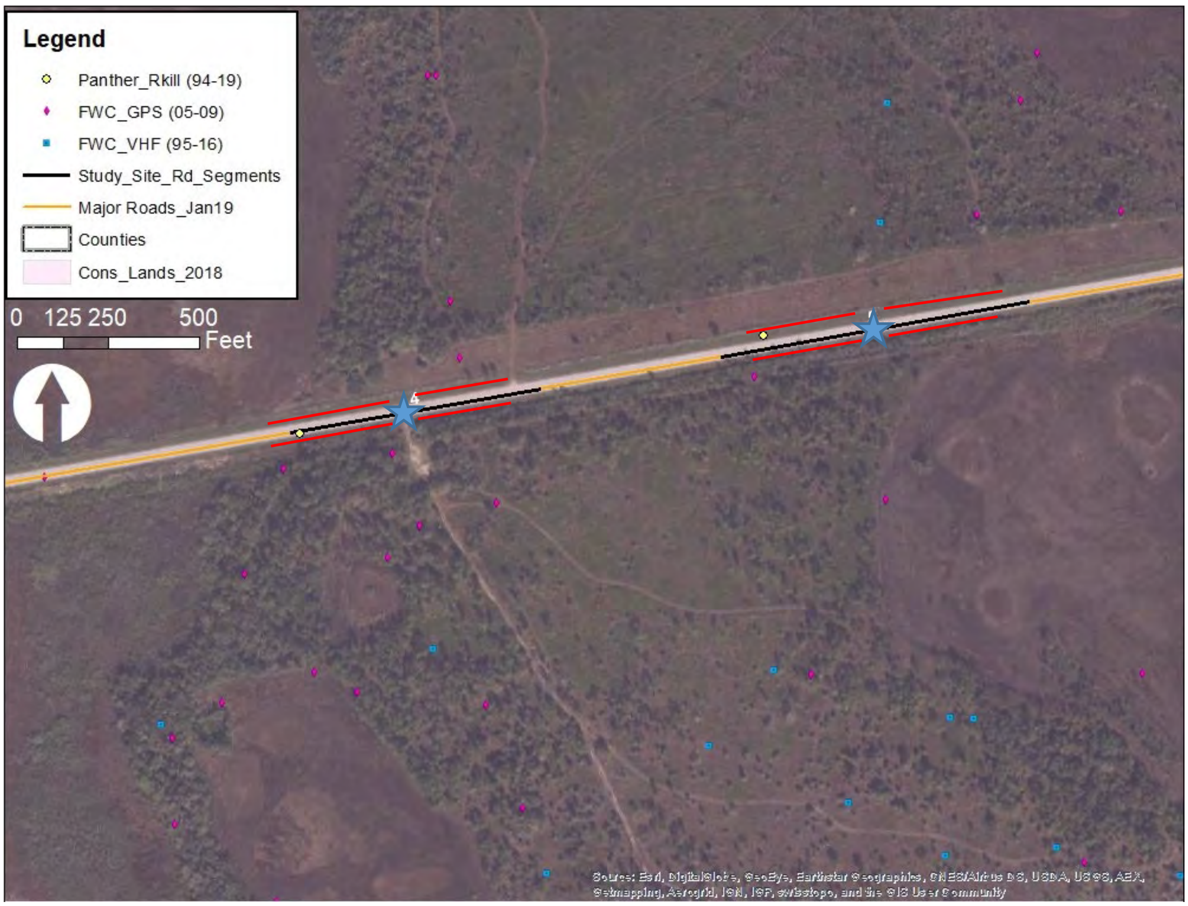

Figure 15. Identified wildlife crossing points at road segments 4-5 in OK Slough SF. The best mitigation (given road geometry, site conditions, and the low traffic volume at this location) may be a "cross-walk" type animal detection/warning system with accompanying wildlife fencing (in red) to direct wildlife to specific crossing points. (Note: A land-bridge over the deep-water channel at site 5 would also be required)

Most telemetry locations occurred in the pinelands at the margins of the marshes, where few exist on the northside of the road between road segments 4 and 5. The latter area consists of dense palmetto/oak scrub, habitat difficult to traverse. This configuration would dictate the need to locate two wildlife crossings. A more economical and effective measure at this location might be the use of a "cross-walk" type animal detection/warning system (Dodd et al. 2009; Dodd and

Wise 2007). This system has proven highly effective in Arizona. Two crosswalk locations with accompanying wildlife fencing would significantly reduce potential for collisions in this area.

Road segment nos. 6 and 7 are located along the west margin of the main portion of the OK Slough flow-way (fig. 16). There are no “dry” land crossings over the southern roadside deep-water channel associated with these sites. We did not monitor road segment no. 7 as high, water levels prohibited it. Even though a panther death occurred from collision in this segment, it likely occurred during a drier period when conditions were more amenable to crossing at this location. In any case, we would not recommend any mitigation for terrestrial wildlife here.

Figure 16. Potential wildlife crossing points at road segments 6-7 in OK Slough SF. This site cluster did not exhibit any “dry” land crossings of the deep-water channel on the south side of Keri Road. White star indicates site for dry crossover of drainage channel.

Road segment no. 6 did not rank very high in our assessment, even though telemetry data would indicate that panthers use this area on both sides of Keri Road. We hypothesize that the deep-water canal choked with dense shrubby vegetation plays a significant role in road crossing frequency at this location. If a land-bridge pathway over the canal was created across from Oil Pad Road, we would expect wildlife crossing activity to increase. To improve overall wildlife connectivity within the ecosystem, we would recommend this action. In addition, the roadway presents a severe barrier to free flow movement of water in the slough. We would suggest installation of multiple culverts along segment no. 7 to reestablish more natural hydraulics to the OK Slough system.

Keri Road East, Road Crossing Patterns and Recommendations:

The Keri Road east study area includes 2 sites (road segment nos. 9 and 10) physically separated by the forest facilities complex and a series of 6 sites (road segments 11-16) similar in character at the eastern end of the State Forest (fig. 8). Potential movement patterns and interaction points with the roadway are shown in Appendix A.

Road segment no. 9 scored the highest for activity by panthers (table 4). Two panther deaths occurred on the road at this location and telemetry activity supports observations on camera of frequent use of this area (fig. 17). As with road segment nos. 4 and 5, this site is best suited for a "cross-walk" type animal detection/warning system. We recommend accompanying wildlife fence extend to at least the length shown in fig. 18, and that it be monitored to evaluate any need to extend the fence to prevent creating new road crossing wildlife hotspots.

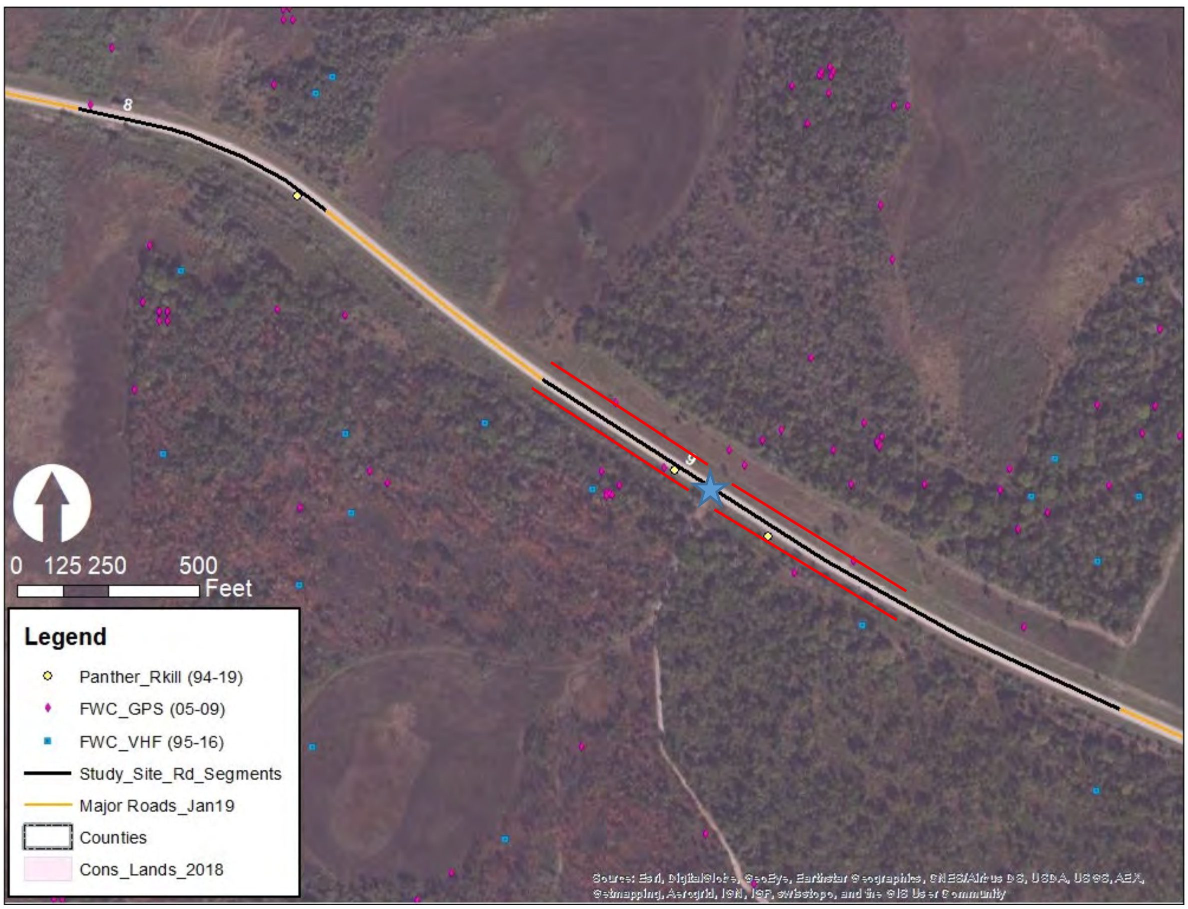

Figure 17. Identified wildlife crossing points at road segments 8-9 in OK Slough SF. The best mitigation (given road geometry, site conditions, and the low traffic volume at road segment no. 9) may be a "cross-walk" type animal detection/warning system with accompanying wildlife fencing (in red) to direct wildlife to a specific crossing point (Keri Tower access road).

Road segment no. 8 was of the same character and site conditions as road segment no. 7 (fig. 16). Because of high water levels we were unable to monitor it. Yet, we suspect "dry" season road crossings by panthers and other wildlife, due to presence of telemetry and roadkill records. We recommend similar measures to that for road segment no. 7: to install multiple culverts along this segment to improve natural hydrologic flows.

The OK Slough forest management facilities are near road segment no. 10 (fig. 18). While some activity by panthers was present at this location (using Twin Mills Grade and the adjacent firebreak), it was not identified as a priority for panthers in the analysis. However, for white-tailed deer activity it scored very high (table 4). This is likely due to the presence of cleared mowed areas for browsing adjacent to extensive forest edge habitat for cover. So, their presence is not necessarily associated with road crossings. The only recommended mitigation action at present would be a land-bridge pathway over the canal across from Twin Mills Grade to improve overall wildlife connectivity within the ecosystem.

Figure 18. Potential wildlife crossing points at road segments 10-11 in OK Slough SF. The unshaded area represents Alico Ranch. The only location we recorded probable panther road crossings was at Twin Mills Road in road segment no. 10. Observations by State Forest staff indicated that panthers may also cross Keri Road on facility grounds. White star indicates site for dry crossover of drainage channel.

We do not recommend any action for road segment 11. Although we did not monitor this location, it likely does not exhibit much road crossing activity due to the extensive marsh habitat on both sides of Keri Road.

The remaining road segments (12-16) are adjacent to the Alico Ranch to the north of Keri Road (fig. 19). The only panther road mortality was recorded in road segment no. 16, just west of Wild Cow Road. Only road segment no. 13 scored in the upper tier of our analysis of abundance for panthers. We did capture panther activity near the roadway and likely crossing the road at Patterson Road (site 13) and Wild Cow Road (site 16). There certainly was activity in the area by collared panthers, yet not at the densities observed further to the west in OK Slough SF.

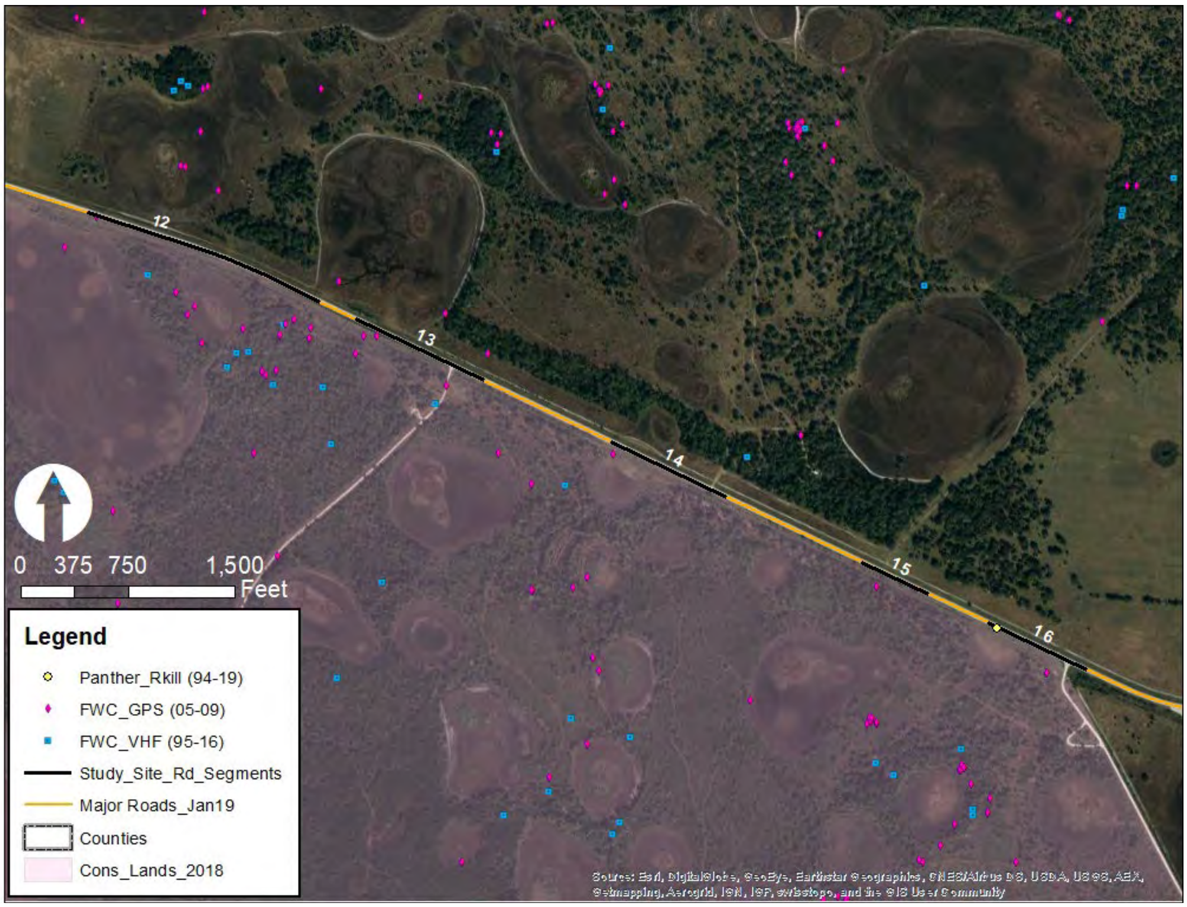

Figure 19. Identified and potential wildlife crossing points at road segments 12-16 in OK Slough SF. The unshaded area represents the Alico Ranch. The only locations we recorded potential panther road crossing activity was at Patterson and Wild Cow Roads in road segment nos. 13 and 16, respectively.

We do not recommend any mitigation actions to reduce vehicle collision risk in this section at this time. This is due to two reasons: 1) the data does not indicate high road crossing rates or collision risk (other than one recorded mortality from 2015), and 2) because the north side of the road is not public conservation land there is insufficient security that the property will remain in passive agriculture or for conservation purposes. Therefore, a significant investment in mitigation is not reasonable without a conservation/agricultural easement or a similar measure of security and coincident increased crossing activity and collision risk.

Despite this recommendation, should conditions change similar “cross-walk” style animal detection/warning systems with associated wildlife fencing as recommended previously would be suitable measures for road segment nos. 13 and 16.

Potential effects and complexities of state process covariables:

Both panther and bobcat abundance in the Keri Road study area were significantly higher at sites without an adjacent canal and with higher percent tree cover. Panther abundance was lower at sites with wider clear zones, but the relationship was not significant. The effect of wider clear zones was the same for bobcats, but significantly so. These relationships translate to more unrestricted mobility and preference of forest cover, consistent with previous studies on habitat selection (Onorato et al. 2011, Land et al. 2008). Bobcat abundance was also higher at sites without access roads, but insignificantly. This may be explained by our placement of cameras along different features that may be used as movement pathways including animal trails, firebreaks, recreational trails, and unpaved, land management access roads. In this instance, trails and firebreaks may be favored travel pathways over the more open and highly maintained vehicle-access roads and recreational trails.

Bear abundance was positively correlated with percent tree cover and foot/bicycle traffic, but insignificantly so. While the correlation with increasing tree cover is consistent with Florida black bear preference for forested habitats (Karelus et al. 2016), the association with foot traffic is less intuitive. This result may reflect the spatial arrangement of resources or site-specific qualities that are not broadly applicable as opposed to foot traffic truly causing higher bear abundance. Another, and perhaps more likely explanation is that in our analysis we were unable to evaluate the effect of timing of presence of people and wildlife and that the positive relationship of foot/bicycle traffic is muddled simply by the mere presence of the road or trail. For instance, from observations on-site and in photographs, we suggest that most people/vehicles are on the roads and trails during daylight hours, while the selected target species are mostly present at twilight and night-time periods. This temporal avoidance behavior would not show up in our statistical analysis and therefore inaccurately indicate a positive connection with foot/bicycle traffic.

Deer abundance was higher at sites without adjacent access roads, but this relationship was insignificant. Much like the explanation provided above for bobcats, this could merely be a preference to avoid people and vehicles. Deer abundance was greater in segments dominated by mesic flatwoods than in segments dominated by oak-cabbage palm forest, but not significantly. This may only be a slight effect of site-specific differences of camera clusters located in OKSSF vs. the Alico Ranch.

It is important to note that the analytical procedure we used identifies the most parsimonious and informative model, and performance is dependent on clear representation of the covariates. In this regard, there is one instance where we included a covariable with somewhat inaccurate representation (foot/bicycle traffic). Access roads/recreational trails were included as a variable to assess potential avoidance of people and vehicles. This was a categorical covariable, and probably more appropriate for the analytical approach we used rather than foot/bicycle traffic. Though more complex (continuous, numeric data), it was inconsequential given we couldn't examine temporal effects. In retrospect, we should have left out foot/bicycle traffic as a covariate and simply used access road/trail to represent this landscape element. Nevertheless, its inclusion doesn't undermine our general findings. Further, we intend to explore other methods to more clearly identify the effects of foot/bicycle and vehicle traffic on species abundance and occurrence, both spatially and temporally.

Of greatest importance, the analysis we used to identify road segments where each species was relatively most abundant is not diminished by the complex nature of interpreting the effects of certain state covariables.

Using N-mixture models to assess road crossing probabilities and collision risk locations:

Royle (2004) defined the N-mixture model that we used and described the output as a "reasonable estimate of abundance based on sparse data". Our estimates are also reasonable and supported by field data such as road mortality sites and telemetry locations and justify our recommendations for potential mitigation measures at the highest wildlife activity areas adjacent to Keri Road.

In a similar context to ours, Santos et al (2018) used a Bayesian hierarchical occupancy detection model to assess locations with higher road crossing risk. We used a Bayesian hierarchical model for abundance/occurrence to identify locations near the road with highest activity levels of the target species as an equivalent to high crossing probability or collision risk.

Santos et al (2018) suggested that their modeling framework provided a means for overcoming bias in road-kill detection and more accurately assessed road crossing risk than raw counts. Our modeling approach likewise was suitable for identifying both current and predicting future collision risk zones. This is pertinent in that, our use of both camera traps and roadkill data to identify roadside locations of high activity by the target species addresses both unsuccessful and successful crossing sites that may change as traffic volume increases over time (also see Schwab and Zandbergen 2011).

Furthermore, Neumann et al (2012) found that roadkill or telemetry data alone were inadequate for assessing road crossing probabilities and collision risk locations. The former tends to overestimate collision risk in certain habitats, while the latter is insufficient to predict collision risk zones. These inadequacies led to our collection of camera trap data (along roadsides) to supplement existing roadkill and telemetry data.

Neumann et al. (2012) also emphasized the importance of spatiotemporal factors in identifying location and timing of collision risk zones. Our findings also demonstrated an influence in spatial arrangement of habitat types and roadside characteristics on locations of highest abundance of each target species. Though we didn't specifically examine diel or seasonal effects, general observations indicate that these did influence timing of increased collision risk.

CORKSCREW ROAD STUDY AREA
RESULTS

Cameras were first deployed at the Corkscrew Road study area in May 2018. We installed a total of 38 cameras during two separate installation periods (early May and early June). All cameras were operational for approximately 12 months, the field work ending in May of 2019. Due to periodic camera malfunctions and obstructions, the number of active camera-trap days varies by site (Table 12). Number of active camera-trap days by site also differs due to the range in number of cameras deployed at each site (see Table 1). These differences were addressed in our statistical evaluation.

Table 12. Active camera-trap days by site and no. of events of target species at Corkscrew Road study area (see fig. 8 for location of study sites).

Study area	Study site/ road segments	Active camera-trap days	All target species	FL panther	Black bear	Bobcat	Whitetail deer
Corkscrew W	0	1426	52	11	0	19	22
Corkscrew W	1	279	45	7	0	2	36
Corkscrew W	2	655	11	0	1	2	8
Corkscrew W	3	1766	167	37	8	75	47
Corkscrew W	4	1056	52	21	0	3	28
Corkscrew N	6	280	7	0	0	6	1
Corkscrew N	7	546	26	0	0	3	23
Corkscrew N	8	336	52	8	0	7	37
Corkscrew N	9	336	120	7	0	8	105
Corkscrew N	10	696	153	6	0	28	119
Corkscrew N	11	664	154	15	0	75	64
Corkscrew N	12	336	103	6	0	2	95
Corkscrew N	14	1373	257	81	10	143	23
Corkscrew N	15	609	11	0	3	1	7
Corkscrew N	16	449	22	6	0	1	15
	Total	**10,807**	**1,232**	**205**	**22**	**375**	**630**

We recorded a total of 1,232 events of the target species (Table 12). Most significant are recorded events of FL panthers (n=205) and their primary prey species, white-tailed deer (n=630). Also, of note are the 375 photo events of bobcats. It is important to note that number of events does not equate to number of individuals. We were unable to identify individuals from photographs. The same individuals likely passed by our cameras numerous times.

Bayesian best estimated unbiased predictors:

The top two measures of abundance for panthers and bobcats were both associated with road segments 11 and 14 but differed for the third measures (Table 13). Black bears were detected at only 4 segments on Corkscrew Road and were highest in road segment 14. Deer were most abundant in road segments 9, 10 and 12.

Site	FL panther	Bobcat	Black bear	Whitetail deer
0	10.33519	7.580648	0	40.74917
1	**22.54763**	10.536818	0	43.49054
2	0	7.095026	72.66336	25.89788
3	15.46777	17.521882	72.27233	58.74828
4	21.50580	4.988763	0	42.56341
6	0	13.980100	0	17.87737
7	0	8.913293	0	35.96873
8	18.38217	14.094903	0	27.87687
9	21.86973	14.505126	0	**78.77906**
10	20.92586	**21.303463**	0	**108.74484**
11	**23.95162**	**40.699933**	0	60.33452
12	20.93526	10.048321	0	**72.78410**
14	**38.79066**	**41.208952**	**77.55734**	40.80511
15	0	10.844449	74.76749	35.45104
16	19.91045	8.156289	0	30.24291

Table 13: Posterior abundance estimates for panther, bobcat and deer at each site on Corkscrew Road as measured by Bayesian best unbiased predictors. The three highest abundance estimates for each species are shown in bold type.

<u>Correlation between covariates</u>:

Several significant correlations between covariates were found in the Corkscrew Road study area (Table 14). In each case where a significant correlation was found, the more informative covariate was selected for each species in each study area (Table 15).

Table 14: Correlations matrix for covariates in the Corkscrew Road study area.

	Adjacent canal	Access road	Centerline to site cluster	Clear zone width	Foot/ bicycle traffic	FWC land cover type	Shrub and tall grass cover	% Tree cover
Adjacent canal	-	0.0852	0.4239	0.0232	0.3962	0.3154	0.4745	0.4035
Access road	-	-	0.0379	0.5262	0.9136	0.3154	0.0565	0.6334
Centerline to site cluster	-	-	-	0.8364	0.9183	0.4926	0.1558	0.9027
Clear zone width	-	-	-	-	0.7872	0.506	0.7376	0.4947
Foot/bicycle traffic	-	-	-	-	-	0.0454	0.2416	0.8908
FWC land cover type	-	-	-	-	-	-	0.2702	0.0031
Shrub and tall grass cover	-	-	-	-	-	-	-	0.0346
% Tree cover	-	-	-	-	-	-	-	-

Note: Significant correlations are listed in red.

Table 15: AIC scores for species abundance models in the Corkscrew Road study area using a single covariate on the state process.

Covariate	FL panther	bobcat	black bear	whitetail deer
Adjacent canal	*530.7455*	*794.7845*	*122.7638*	1759.617
Access road	533.818	801.0462	120.0845	1794.674
Centerline to site cluster	*537.1731*	*801.8479*	*123.7259*	*1796.491*
Clear zone width	497.908	754.9072	121.6838	*1797.914*
Foot/bicycle traffic	*537.0744*	*804.1461*	123.734	*1756.695*
FWC land cover type	497.7836	726.9779	*123.2446*	1709.564
Shrub and tall grass cover	530.349	767.8387	*119.819*	1756.286
Percent tree cover	*529.7126*	*804.6935*	115.3465	*1766.058*

Note: Covariates eliminated from further consideration are shown in gray italics.
Covariates included in the final models for each species were identified by selecting for the lowest AIC score (above) in highly correlated pairs (see Table 14).

<u>Species relative abundance models</u>:

Abundance models containing only the covariate of active camera days showed significant effects on the detection process (FL panther, p=2.28e-14; bobcat, p=2.14e-16; black bear, p=1.33e-02; and whitetail deer, p=0.0196). Shapiro-Wilk normality tests indicated the distribution of events for each species was not normal (FL panther, p<0.0001; bobcat, p<0.0001; black bear, p<0.0001; whitetail deer, p=0.0080), therefore the nonparametric Wilcoxon analysis was used in categorical comparisons.

The best fitting FL panther model (Active days ~ Access Rd + Clear zone width + FWC land cover type; AIC = 494.421) indicated abundance was higher in road segments without an access road, but the association was not significant (Wilcoxon, p=0.9525). However, there was a significant positive correlation between panther abundance and clear zone width (p=0.0051, R^2=0.4655). Panther abundance was also higher in segments associated with FWC land cover categories of *mesic flatwoods* and *marsh impoundments* than with *citrus* or *shrub and brush*, but not significantly so (Wilcoxon, p=0.6034). Results from all panther models are shown in Table 16.

The top performing bobcat model (Active days ~ Access Rd + Clear zone width + FWC land cover type + Shrub and tall grass cover; AIC = 669.476) indicated higher bobcat abundance in segments with no access road present, but this association was insignificant (Wilcoxon, p=0.5146). Yet there was a significant positive correlation between bobcat abundance and clear zone width (p=0.0071, R^2=0.439). Regarding FWC land cover categories, abundance was higher in *citrus* and *mesic flatwoods* than in *marsh impoundments* and *shrub and brush*, but this relationship was also insignificant (Wilcoxon, p=0.7628). Bobcat abundance was higher in the shrub and tall grass cover middle category (1/3-2/3), but not significantly so (Wilcoxon, p=0.0764). Results from all bobcat models are listed in Table 17.

Table 16. AIC (of best-fitting model) and Δ AIC (from best-fitting model) for all 15 considered FL panther abundance models in the Corkscrew Road study area.

Covariate combinations	Δ AIC from best-fitting model	AIC
Access Rd + Clear zone + FWC	0	494.421
Access Rd + Clear zone + FWC + Shrub and tall grass	1.8853	496.306
FWC	3.363	497.7836
Clear zone	3.4874	497.908
Clear zone + FWC	3.4874	497.908
Access Rd + FWC	3.9063	498.327
FWC + Shrub and tall grass	5.2742	499.695
Clear zone + FWC + Shrub and tall grass	5.4558	499.876
Access Rd + FWC + Shrub and tall grass	5.8837	500.304
Clear zone + Shrub and tall grass	18.2366	512.657
Access Rd + Clear zone + Shrub and tall grass	18.9053	513.326
Access Rd + Clear zone	22.4243	516.845
Shrub and tall grass	35.9284	530.349
Access Rd + Shrub and tall grass	37.6252	532.046
Access Rd	39.3974	533.818

Table 17. AIC (of best-fitting model) and Δ AIC (from best-fitting model) for all 15 considered bobcat abundance models in the Corkscrew Road study area.

Covariate combinations	Δ AIC from best-fitting model	AIC
Access Rd + Clear zone + FWC + Shrub and tall grass	0	669.476
Clear zone + FWC + Shrub and tall grass	2.0538	671.53
FWC + Shrub and tall grass	25.0424	694.518
Access Rd + FWC + Shrub and tall grass	26.577	696.053
Access Rd + Clear zone + Shrub and tall grass	45.7726	715.248
Clear zone + FWC	47.8694	717.345
Access Rd + Clear zone + FWC	49.8676	719.343
Clear zone + Shrub and tall grass	53.7365	723.212
Access Rd + FWC	57.4714	726.947
FWC	57.5021	726.9779
Clear zone	85.4314	754.9072
Access Rd + Clear zone	86.9199	756.396
Shrub and grass	98.3629	767.8387
Access Rd + Shrub and tall grass	99.9947	769.471
Access Rd	131.5704	801.0462

The best-fitting black bear model (Active days ~ Percent tree cover; AIC = 115.3465) indicated a positive but insignificant correlation between percent tree cover and bear abundance (p=0.8024, R^2=0.0391). Results from all bear models are shown in Table 18.

Table 18: AIC (of best-fitting model) and Δ AIC (from best-fitting model) for all 15 considered black bear abundance models in the Corkscrew Road study area.

Covariate combinations	Δ AIC from best-fitting model	AIC
Percent tree cover	0	115.3465
Access Rd + Percent tree cover	1.1745	116.521
Clear zone + Percent tree cover	1.5499	116.896
Access Rd + Foot traffic + Percent tree cover	1.839	117.186
Foot traffic + Percent tree cover	1.9456	117.292
Access Rd + Clear zone + Percent tree cover	2.1617	117.508
Clear zone + Foot traffic + Percent tree cover	3.403	118.75
Access Rd + Clear zone + Foot traffic + Percent tree cover	3.7995	119.146
Access Rd	4.738	120.0845
Access Rd + Foot traffic	4.7931	120.14
Clear zone	6.3373	121.6838
Access Rd + Clear zone	6.5001	121.847
Access Rd + Clear zone + Foot traffic	6.7246	122.071
Clear zone + Foot traffic	8.2862	123.633
Foot traffic	8.3875	123.734

The best-fitting whitetail deer model (Active days ~ Adj canal + Access Rd + FWC land cover type + Shrub and tall grass cover; AIC = 1662.46) indicated deer abundance was higher in road segments with an adjacent canal and without an access road, but these relationship were not significant (Wilcoxon, p=0.6371 and p=0.5165, respectively). Bobcat abundance was greatest in road segments where mesic flatwoods was the dominant FWC land cover category, but not significantly so (Wilcoxon, p=0.3072). Lastly, deer abundance was higher in segments characterized by the shrub and tall grass cover middle category (1/3-2/3), but again the relationship was insignificant. Results from all deer models are listed in Table 19.

<u>Other effects</u>:

We collected rainfall and temperature data from the nearest station at Ft. Myers/Naples Airport for the study period May 2018 to May 2019 (fig. 20). There was a peak in rainfall from May to August. This resulted in flooding of all sites within or near marsh areas, making these locations somewhat inaccessible. This also resulted in elevated water levels in roadside channels and swales increasing the barrier effects of the road to terrestrial wildlife movement.

We also examined the effect of season on the number of events recorded for each species group. Based on the data collected, we defined species groups as carnivores (black bear, bobcat, coyote, river otter), ungulates (white-tailed deer, wild hog), meso-mammals (Virginia opossum, raccoon, nine-banded armadillo), small mammals (rabbits), and avian (wild turkey and sandhill crane). Panthers were evaluated separately. Sites along Corkscrew Road West are shown in fig. 21 (and in tabular form in Appendix F), and sites along Corkscrew Road North are shown in fig. 22 (and in tabular form in Appendix F). Meso- and small- mammals are only shown in Appendix F.

Table 19: AIC (of best-fitting model) and Δ AIC (from best-fitting model) for all 15 considered whitetail deer abundance models in the Corkscrew Road study area.

Covariate comparisons	Δ AIC from best-fitting model	AIC
Adj canal + Access Rd + FWC + Shrub and tall grass	0	1662.46
Adj canal + FWC + Shrub and tall grass	10.5	1672.96
Adj canal + Access Rd + FWC	17.96	1680.42
Adj canal + FWC	23.454	1685.91
Access Rd + FWC + Shrub and tall grass	33.742	1696.2
FWC + Shrub and tall grass	35.837	1698.29
Access Rd + FWC	46.648	1709.1
FWC	47.109	1709.564
Adj canal + Access Rd + Shrub and tall grass	47.817	1710.27
Adj canal + Shrub and tall grass	66.826	1729.28
Shrub and tall grass	93.831	1756.286
Access Rd + Shrub and tall grass	94.45	1756.91
Adj canal + Access Rd	96.869	1759.32
Adj canal	97.162	1759.617
Access Rd	132.219	1794.674

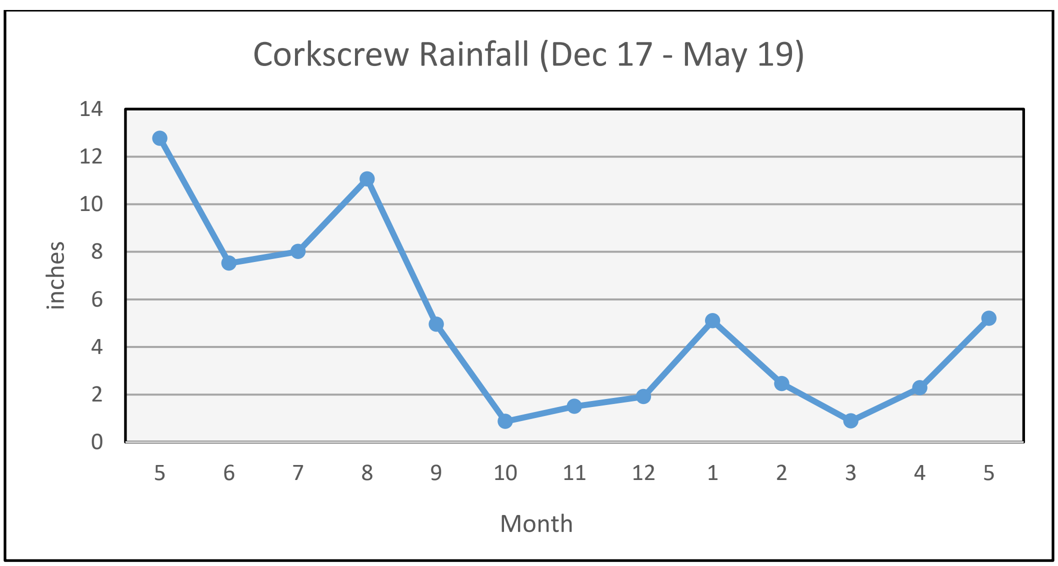

Figure 20. Approximate rainfall amounts for the Corkscrew Road study area (Ft. Myers/Naples Airport data from: NOAA 2019).

At the Corkscrew Road West study area, panthers were most commonly recorded at sites S3, S4 and S0, in that order (fig. 21). The Fall season exhibited the greatest activity. For other carnivores (mostly bobcats), site S3 had the greatest use. In this case the greatest activity occurred in Summer and Fall. Ungulates included mostly deer; they were more frequently captured on camera than any other species. Sites S3 and S1 had the highest number of deer, most often recorded in Fall. Few Avian events were recorded at all sites across all seasons. Notably events of American alligator recorded were minimal, surprising given the amount of water in the impoundment areas in summer at The Place, CMB and Imperial Marsh Preserve. Event records were negligible for all species groups at site S2; this site did not include dry access over the roadside channel and the shrub vegetation growing in the canal was dense.

At the Corkscrew Road North study area, only site S14 exhibited frequent use by panthers, all other sites had nominal events, except S6, S7 and S15 that had none (fig. 22). No seasonal differences were notable. With other carnivores, bobcats again exhibited the dominant presence, especially at S14 and S11. Like panthers, bobcat activity didn't adhere to any seasonal preference. White-tailed deer represented most ungulates at Corkscrew Road North; there were over twice as many as recorded at Corkscrew Road West. Sites S10, S9, S12 and S11 had the highest numbers, in that order. They were most frequently recorded from Spring to Fall. Avian events (mostly turkey) were highest at site S10. Spring had the highest number of Avian events. Site S6 and S15 had minimal activity by all species groups.

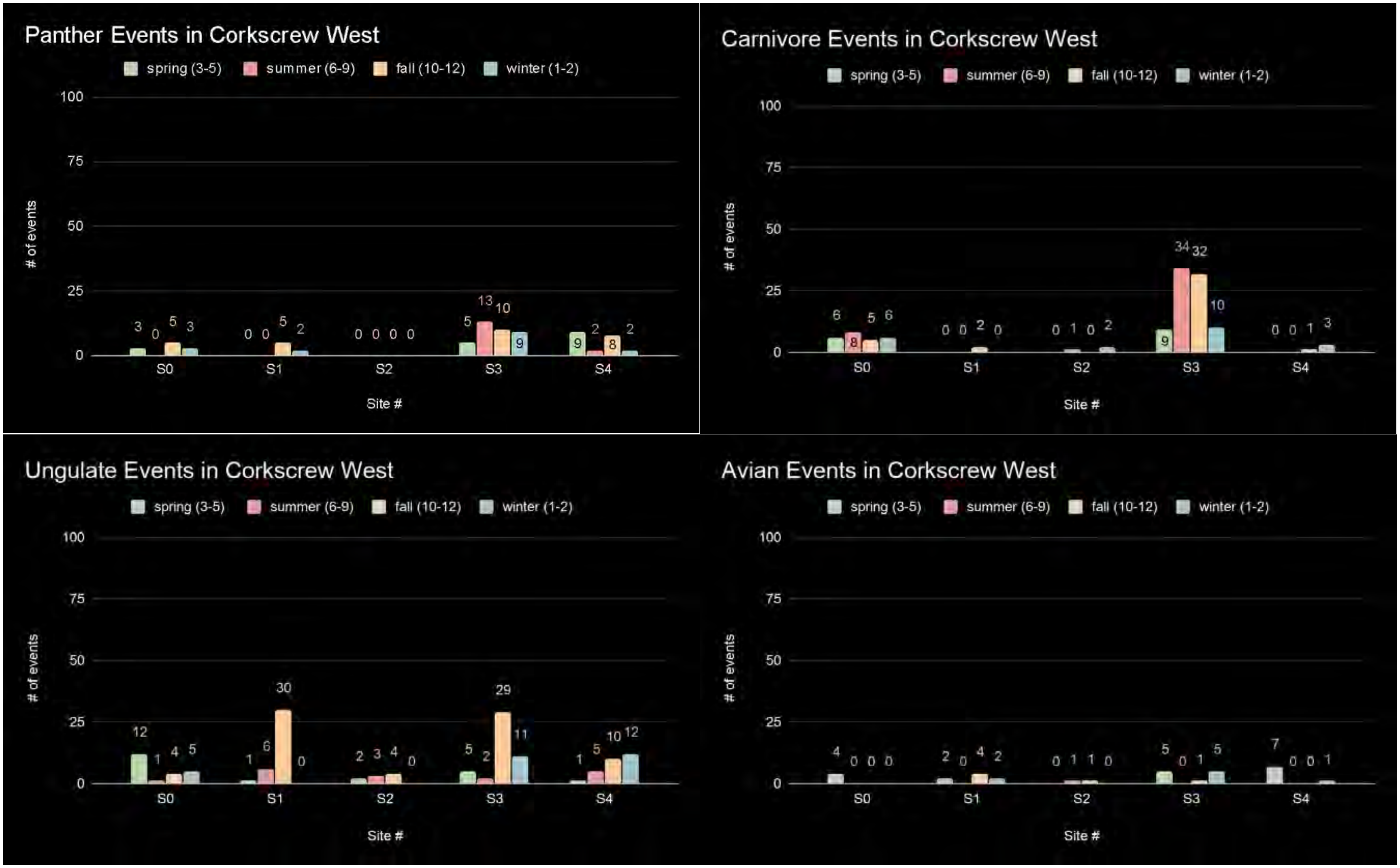

Figure 21. Number of Photo Events by Season by Species for Corkscrew Road West (see fig. 9 for site locations). For meso- and small- mammal event records, see Appendix F.

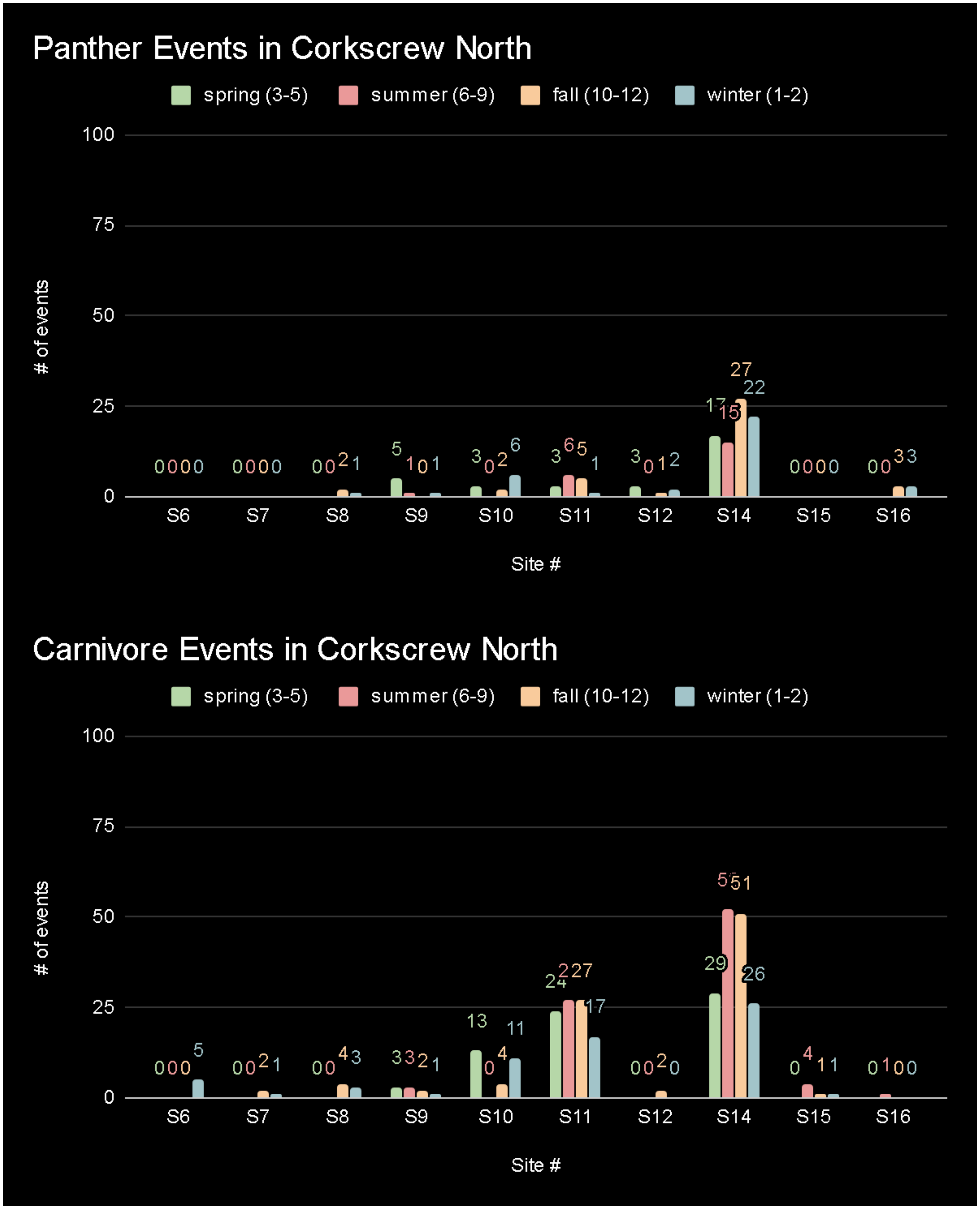

Figure 22. Number of Photo Events by Season by Species for Corkscrew Road North (see fig. 9 for site locations). For meso- and small- mammal event records, see Appendix F.

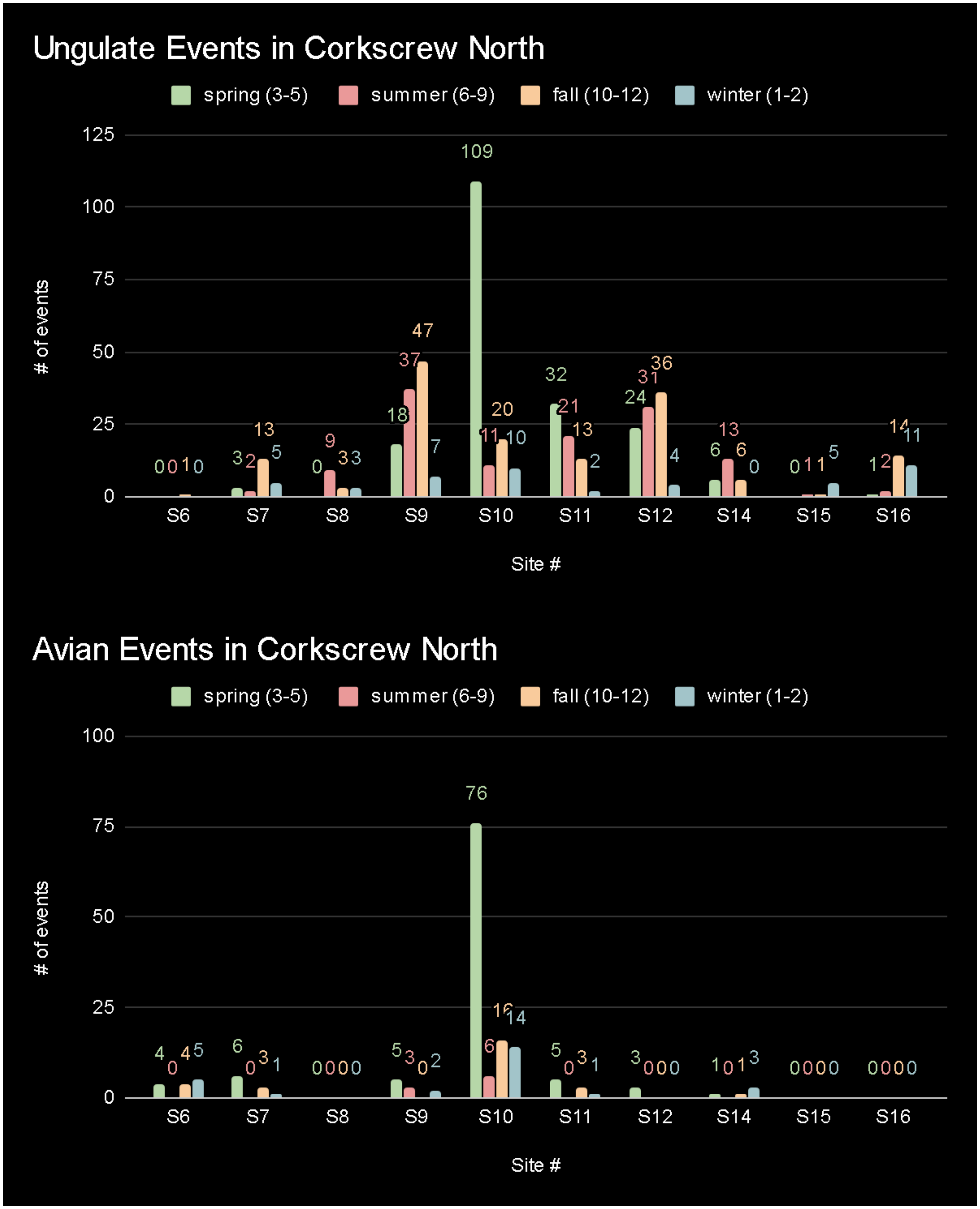

Figure 22. continued.

CORKSCREW ROAD STUDY AREA
DISCUSSION

Field surveys on Corkscrew Road revealed similar parallel roadside swales and a deep irrigation/drainage channel adjacent to the groves. These channels were maintained and dredged with approximate widths of 20-25 and depths up to 15 ft below the raised berm along that side of the road. Wide roadside swales were adjacent to the CREW property, the Corkscrew Mitigation Bank and Imperial Marsh Preserve. Though the swales, at times, may present an obstacle to animal road crossings, they didn't interfere with our roadside animal trail surveys. Five of the sites we monitored were negatively impacted by the deeply carved irrigation/drainage channels.

Our general findings for Corkscrew Road West indicate that with habitat restoration measures, sites S0 (The Place), S3 (CMB) and S4 (Imperial Marsh) could become key road crossing locations for panthers. This is supported by a few scattered telemetry locations within the former groves that occurred between the Airport Mitigation Bank and Corkscrew Swamp Sanctuary. Another potential Corkscrew Road crossing location for panthers in this section of Corkscrew Road is just to the east of the Titan Mine through a Lee County parcel that sits between Imperial Marsh and Corkscrew Swamp Sanctuary. Again, there are telemetry locations that indicate this may already act as a road crossing location for panthers. We were unable to obtain permission to monitor this location for potential use.

On Corkscrew Road North, our results indicate one crossing location (S14) frequently used by panthers. This site coincides with the existing canal under the roadway near the entrance to Alico groves. This canal includes a dense, shrubby strip corridor that leads to SR 82 and a planned site for a wildlife crossing structure. Another site where panther activity was nominal was site S11, where the adjacent irrigation canal is bridged. This appears to be an access point for carnivores to hunt in the groves. We observed panthers, bobcats and coyotes using this location.

Corkscrew Road at present has traffic volume of 4,400 to 7,800 vehicles/day. These levels pose a significant risk for animal-vehicle collisions and result in greater road crossing avoidance behavior (Schwab and Zandbergen 2011). This is worsened by commonly observed high-speed travel. The physical aspects of the roadway-- steep shoulders, adjacent swales and canals and narrow clear zones create little warning to drivers of oncoming animals attempting to cross the road. Because of these conditions, the least expensive remedy for collisions would be a reduced posted speed and increased enforcement. Mitigation for safe wildlife crossings along Corkscrew Road is further complicated by multiple private land ownership and an active real estate and development climate (particularly along Corkscrew Road west study area).

We identified several road crossing locations used by wildlife, facilitated by access roads and trails that allow wildlife to cross adjacent deep-water channels used primarily for agricultural activities. As such, crossing opportunities are potentially many and several challenges exist, both economically and practically, to address entirely with wildlife crossing structures and fencing. Below we provide recommendations based on greatest need, but many of these locations are dependent upon large-scale land use and conservation planning practice.

Corkscrew Road West, Road Crossing Patterns and Recommendations:

Corkscrew Road west study area included 6 road segments, 5 of these were adjacent to protected conservation areas and were monitored (sites 0-4) (fig. 23). To the south were active or abandoned groves and cropland. Access roads were monitored at road segments 0, 1, 2 and 4. Only road segment no. 1 ranked among the top three in our model of posterior abundance estimates (table 14). The low score for road segment no. 0 is certainly reflective of the current cleared/disturbed condition prior to restoration as an upland pine habitat site. Low to medium scores at sites 2, 3 and 4 are also reflective of the character of these areas, dominated by large impoundment wetland areas with strip upland habitat on the north side of the road and commercial agriculture on the south side of the road.

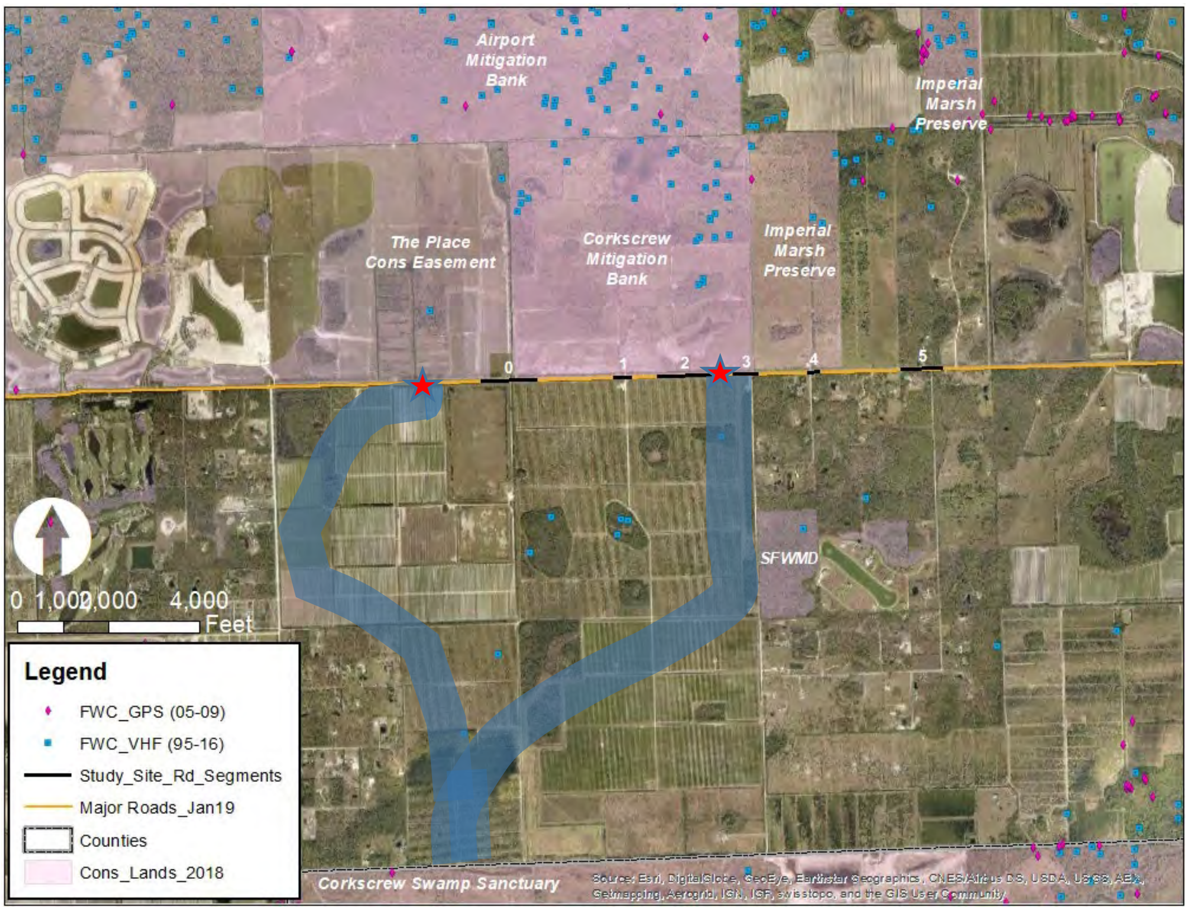

Figure 23. Identified and potential wildlife crossing points at road segments 0-5 on Corkscrew Road. Blue shaded areas represent conceptual conservation linkages between Corkscrew Swamp Sanctuary and the Corkscrew Mitigation Bank and The Place Conservation Easement (upland restoration area). These linkages are proposed at approx. 750 to 1000 ft in width.

Wildlife road crossings in this case are less about existing conditions and more about proposed land use and conservation planning proposals. A proposal to develop the property on the south side of the road (Verdana/Pepperland) would include two wildlife linkages that would assist in restoring historic hydrologic flow patterns (fig. 23). Note the representation shown here is that of the authors, not the property owners and is conceptual in nature generally overlaying where historic wetland systems used to exist prior to transformation to commercial agriculture. If this proposal becomes a reality, we would recommend wildlife crossing structures where each of these linkages intersect with Corkscrew Road. Site and structural details would have to be worked out as the plans move forward.

An aspect of this that would be required on the Corkscrew Mitigation Bank property to the north at road segment no. 3 is to provide a narrow upland linkage to the wildlife crossing structure from the eastern boundary of the property. This would likely require some reshaping of the impoundment area at the southeast corner of the property. The best and most effective options including details and engineering of this undertaking would have to be investigated as the proposal moves forward.

Considerable panther activity was observed at road segment no. 4 (Imperial Marsh Preserve), though it had a moderate ranking in our analysis. This location is across from a large-lot residential area to the south. This does not provide for any opportunities to include wildlife crossing structures; however, it is entirely reasonable (from our photo evidence and scant telemetry data) to assume panthers do cross at this location and move through the low-density residential area where a substantial amount of the native pine canopy and understory vegetation remains. At present, no panther mortalities have been recorded, however as traffic continues to increase, the road will become more of a barrier to wildlife movement. No mitigation is recommended at present, but this location should remain a watch area for increased risk of animal-vehicle collisions with time.

Although we were unable to obtain permission to monitor it as part of this study, the area shown in fig. 24 does include potential panther crossing locations of Corkscrew Road between the Imperial Marsh Preserve to the north and the CREW and Corkscrew Swamp to the south. Telemetry data indicates that this has been used in the past as a travel pathway between the two areas. Lee County has a significant holding within this travel pathway. We recommend considerations be made to establish a connecting conservation corridor at this location to improve access and use of the Imperial Marsh area by panthers. Providing multiple connections from CREW/Corkscrew Swamp to the greater Imperial Marsh ecosystem (consisting of several conservation easements, mitigation banks and county preserves) increases its value to panthers.

Corkscrew Road North, Road Crossing Patterns and Recommendations:

Two distinct landscape contexts exist in the Corkscrew Road north study area. To the east is public conservation lands (CREW), to the west is active commercial groves (fig. 9). Road segment no. 11 was among the top three ranked sites for panther activity (table 14, fig. 25). This location along with road segment no. 10 provided dry access to the groves and were near a large natural area within the groves. These sites also had high numbers of deer activity. There were 2 panther roadkills recorded at the main trailhead entrance. We did not monitor this site because of the level of human activity.

Although panthers and other wildlife do utilize the groves, it’s impractical to plan wildlife crossings or other mitigation measures to enhance connectivity between the two different land uses. Any actions to improve safe access by wildlife to the groves would require a partnership between the State and Alico Inc. Long-term plans for the groves beyond its use as agriculture would have a strong bearing on future use of the area by panthers and other wildlife. Outside of any agreements between these two parties, if wildlife-vehicle conflicts worsen in this area, exclusionary fencing might be an option. The other option that maintains the current level of connectivity between the two areas, is the use of roadside animal detection systems. However, relative priorities to provide for wildlife connectivity would preclude a significant expenditure on this technology for this area at present.

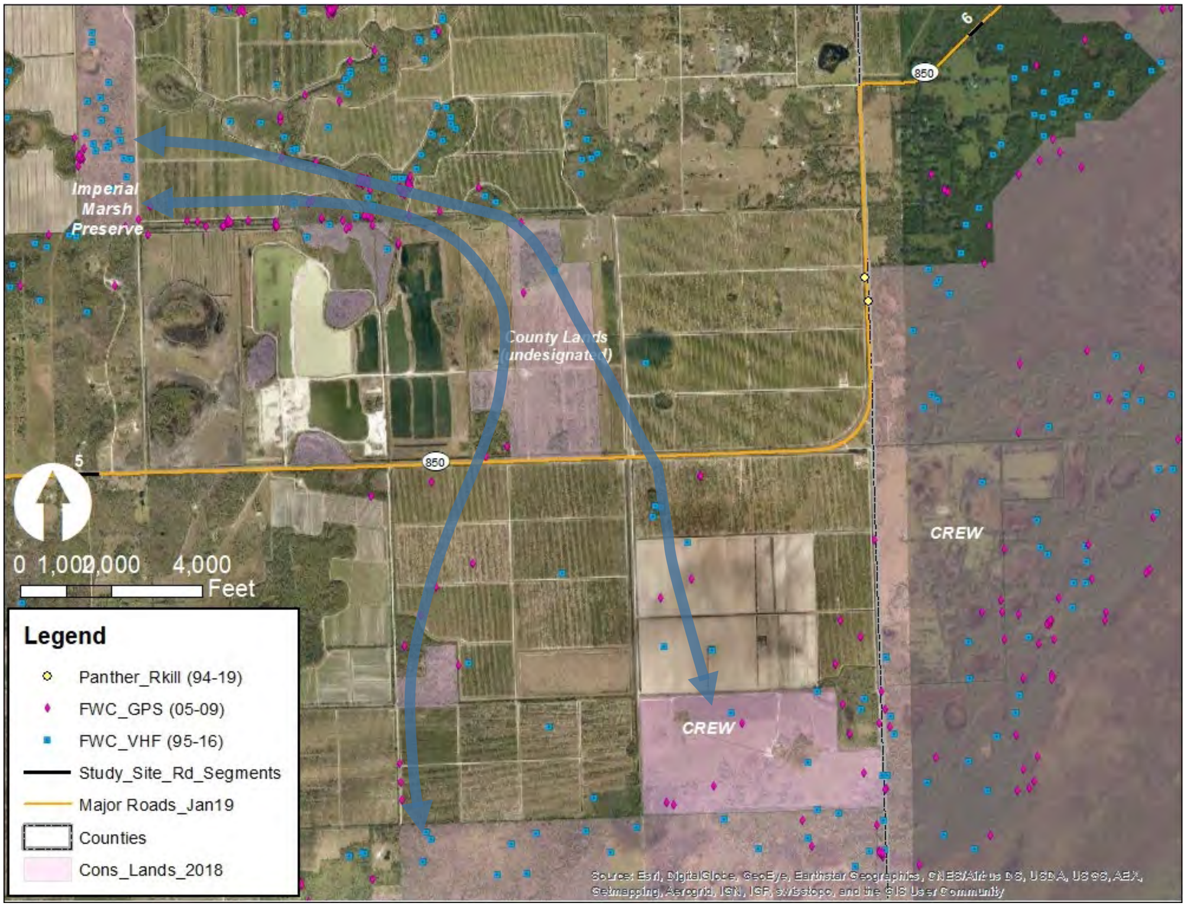

Figure 24. Potential wildlife crossing points on Corkscrew Road between Imperial Marsh Preserve and CREW. Blue arrows represent generalized travel pathways (based on telemetry data) between Imperial Marsh Preserve and CREW/Corkscrew Swamp Sanctuary.

Road segment nos. 14 and 15 are at the northern end of the CREW lands and also border the Alico Inc. groves (fig. 26). These sites are highlighted by two different land use elements, a canal crossing under Corkscrew Road (site 14) and a power transmission line easement (site 15). Next to the canal is the main access road to Alico Inc. groves and therefore a dry access point over the irrigation canal along the border of the groves.

Road segment 14 ranked highest for panther activity among all Corkscrew Road sites. In addition, one panther road mortality was recorded at this location. This location provides a strip corridor between the CREW lands to SR 82 where FDOT is planning to install ledges under the highway for wildlife passage. As such, this site should be considered for similar measures on

Corkscrew Road. Enlarging the existing culvert and installing wildlife ledges would provide safe passage under Corkscrew Road. Wildlife fencing would be needed to direct wildlife to the structure on each side of the canal. A significant impediment to this mitigation is the proximity of the Alico entrance road, chiefly because the roadbed would have to be raised to accommodate a larger culvert fitted with dry path ledges for wildlife.

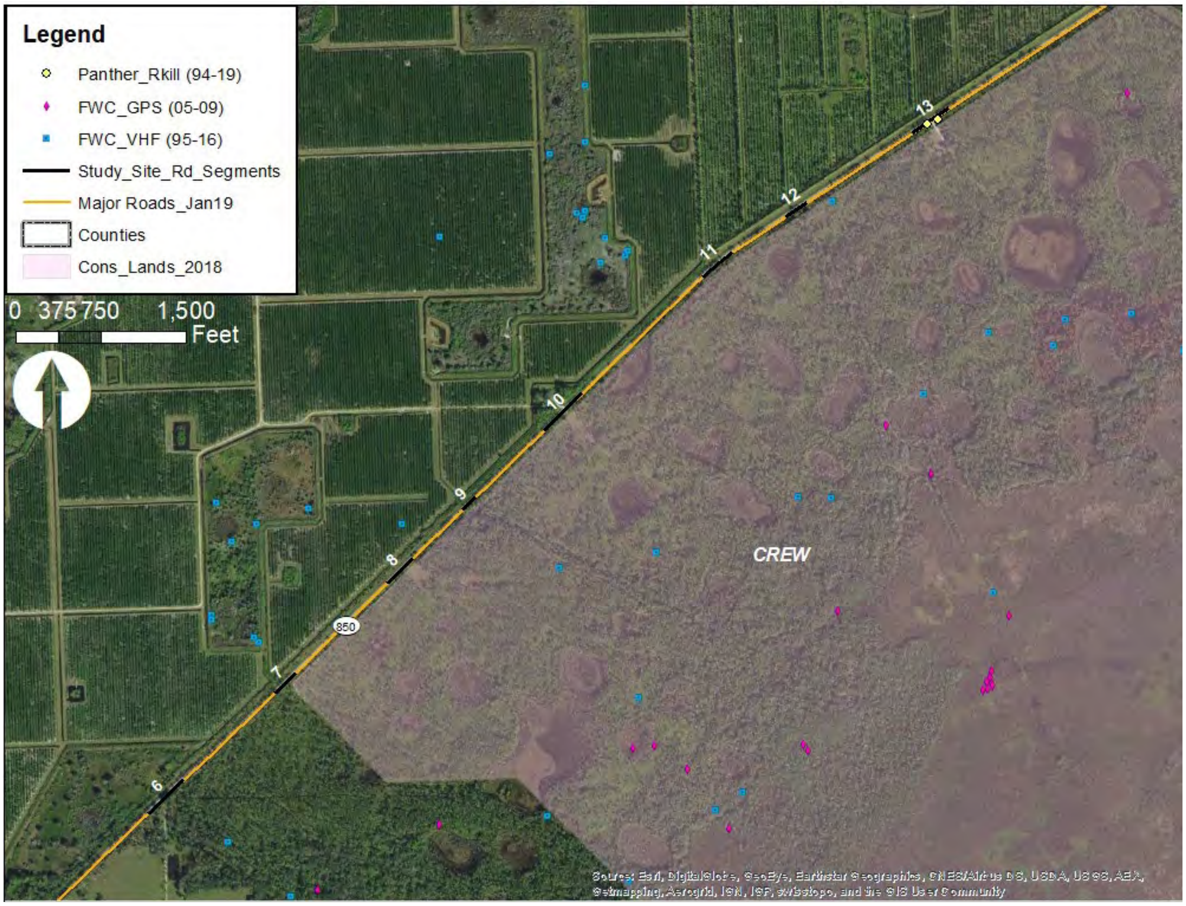

Figure 25. Identified wildlife crossing points on Corkscrew Road between Alico Inc. groves and CREW. Road segment nos. 10 and 11 were the only sites where access roads allowed dry crossing opportunities over the border irrigation canal within the groves. Telemetry locations (in blue) show panther use of internal natural areas within the groves.

We did not record significant wildlife use of the powerline corridors at road segment no. 15 (fig. 26). The powerline corridor is located directly across from residential housing and a commercial site. Due to its location and overall low ranking in our analysis, we do not recommend any mitigation at this location. One additional site monitored, road segment no. 16 (see fig. 9) included an access road that crossed all the canals, yet it was a significant distance through the groves between CREW and SR 82. We recorded minimal wildlife use here, but it was a busy road for grove vehicles and did not include much vegetation cover. At present, it is not a suitable location for wildlife crossing measures.

Figure 26. Identified wildlife crossing points at road segment nos. 14 and 15 on Corkscrew Road. Road segment no. 14 includes a large culvert for a canal that crosses under Corkscrew Road. This canal continues north to SR 82 where FDOT is constructing ledges under the road for wildlife passage. The blue star indicates the location of the existing culvert for the canal.

Potential effects and complexities of state process covariables:

In road segments along Corkscrew Road, higher panther and bobcat abundance were both significantly correlated with wider clear zones. This is contrary to the findings for Keri Road. We think this may be associated with site-specific qualities (i.e., repeated use by panthers and bobcats of two canal crossings along Corkscrew Road that coincide with the widest sections of the clear zone).

Regarding land cover, panthers were more abundant at sites dominated by mesic flatwoods and marsh impoundments than sites where citrus and shrub and brush were dominant. This is explained by site-specific spatial arrangement. The two sites where we recorded the greatest number of panther photo events, were in mesic flatwoods in the CREW and in the narrow tree-lined strip corridors surrounded by expansive marsh impoundments in the Corkscrew Mitigation Bank. Bobcat abundance was greater at sites with land cover types of citrus or mesic flatwoods (found more prominently at Corkscrew North) over marsh impoundments or shrub and brush (more common to Corkscrew West). With respect to influence of vegetation, bobcat abundance was higher (but insignificantly so) in the shrub and tall grass cover middle category (1/3-2/3), which may be more suitable for hunting small prey.

As was the case in the Keri Road study area, percent tree cover was also positively (but insignificantly) correlated with bear abundance in the Corkscrew Road study area. However, this result is within the context of very few bear captures during the study period.

Deer abundance in Corkscrew Swamp was higher at sites without adjacent access roads, but this relationship was insignificant. As with the situation at Keri Road, this could merely be a preference to avoid people and vehicles. Bobcat abundance was greatest in road segments where mesic flatwoods was the dominant land cover type. This is notably the same land cover preference exhibited at the Keri Road study site.

It is important to note that the analytical procedure we used identifies the most parsimonious and informative model, and performance is dependent on clear representation of the covariates. In the context of Corkscrew Road, we may have under-represented the effect of land cover. We used a basic approach to land cover effect by only including the dominant land cover type within a 0.2 ha area around the centroid of each camera cluster. Therefore, the importance of any secondary land cover types within the study sites was not evaluated (see above example regarding panthers and "primary" use of narrow tree-lined strip corridors). For the Corkscrew Road study area this may have been inadequate but is easily explained from the results with knowledge of site specifics.

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