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The ecological impact of humans and dogs on wildlife in protected areas in eastern North America

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ABSTRACT

The establishment of protected areas is a key strategy for preserving biodiversity. However, human use of protected areas can cause disturbance to wildlife, especially in areas that allow hunting and if humans are accompanied by dogs (*Canis familiaris*). We used citizen-science run camera traps to investigate how humans, dogs and coyotes (*Canis latrans*) used 33 protected areas and analyzed behavioral responses by three prey species: white-tailed deer (*Odocoileus virginianus*), eastern gray squirrel (*Sciurus carolinensis*) and northern raccoon (*Procyon lotor*). We obtained 52,863 detections of native wildlife, 162,418 detections of humans and 23,332 detections of dogs over 42,874 camera nights. Most dogs (99%) were on the trail, and 89% of off-trail dogs were accompanied by humans. Prey avoided dogs, humans and coyotes temporally, but did not avoid them spatially, or greatly increase vigilance. Our results indicate that humans are perceived as a greater risk than coyotes, and this increases when dogs accompany their owners. The concentration of dogs on the trail with their owners, and relatively minor behavioral impacts on prey, contrasts the strong negative ecological effects found in studies of free-ranging dogs. We found dog management to be effective: prohibiting dogs in protected areas reduced their use of an area by a factor of 10 and leash laws increased leashing rates by 21%. Although millions of dogs use natural areas in North America each year, regulations enacted by protected areas combined with responsible management of dog behavior greatly reduce the ecological impact of man's best friend.

1. Introduction

The establishment of protected areas is a key strategy for preserving biodiversity. Although they preserve habitat, protected areas typically do not eliminate human presence. On the contrary, people visit protected areas an estimated 8 billion times around the world every year, including 2 billion in the United States (Balmford et al., 2015). Nature recreation is important for conservation because it helps connect people with nature and broadens the constituency that values protecting land from development (Balmford et al., 2002; Wells and Lekies, 2006). However, human use of these areas can cause disturbance to wildlife, threatening the biodiversity preservation goals of protected areas.

Disturbance of wildlife by recreationists may provoke anti-predator responses such as fleeing, increasing vigilance, and changes in habitat use (Frid and Dill, 2002). Since there is a trade-off between avoiding a perceived risk and other fitness-enhancing activities, like feeding and finding a mate, disturbances by recreationalists can reduce animal fitness by disrupting optimal feeding, parental care, or mate choice (Beale, 2007; Beale and Monaghan, 2004; Frid and Dill, 2002). The risk-disturbance hypothesis provides a framework for understanding wildlife-human interactions, where responses by disturbed animals can be directly attributed to disturbance stimuli, responses being stronger when perceived risk is greater (Frid and Dill, 2002).

Human-caused disturbance can be compounded in areas that allow hunting (Frid and Dill, 2002) and if humans are accompanied by dogs (*Canis familiaris*) (Banks and Bryant, 2007; Miller et al., 2001; Weston and Stankowich, 2014). There are an estimated 78 million domestic dogs living in the United States (Gompper, 2014) and many owners visit protected areas with their dogs each year (Hughes and MacDonald, 2013). Protected areas often have leash laws which could

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limit the interactions of dogs with wildlife, while others prohibit the dogs altogether. However, little data exist to evaluate the effectiveness of these policies in terms of ecological impacts, the extent to which owners obey leash laws, or how often dogs move off-trail and interact with wildlife (Ritchie et al., 2014; Vanak et al., 2014). While the lethal impacts of dogs on wildlife have been shown (Young et al., 2011), the indirect effects of dogs on vigilance (Vanak et al., 2009), feeding rates (Vanak et al., 2009), space use (Grignolio et al., 2011) and fecundity (Sheriff et al., 2009) of native wildlife is of equal concern. In a review of 69 peer-reviewed studies on dog-wildlife interactions, only three concluded that dogs had no impact (Hughes and MacDonald, 2013).

As development encroaches around protected areas in the United States and human use of these areas increases (Radeloff et al., 2010), understanding the impacts of recreation on wildlife is a key priority. Our previous research found that hiking and managed hunting did have an effect on mammal distribution, though to a lesser extent than habitat, however an analysis of the effect of dogs as an agent of disturbance was not considered (Kays et al., 2016). Thus, in this study we used the same camera trapping survey to investigate the use of protected areas by humans and dogs in the eastern United States. We predicted that most humans and dogs would be found on trails, and that leash laws would significantly decrease off-trail dog activity. To put the effects of humans and dogs in perspective, we compared the strength of their indirect ecological effects on wildlife with those of the second largest natural predator, coyotes (*Canis latrans*). We quantified these effects by evaluating the spatial and temporal avoidance of potential predators by three common prey species that vary in activity patterns (crepuscular, diurnal, nocturnal): white-tailed deer (*Odocoileus virginianus*), eastern gray squirrel (*Sciurus carolinensis*) and northern raccoon (*Procyon lotor*). We also examined the effect of predator presence on white-tailed deer vigilance. Based on the risk-disturbance hypothesis, we predicted that wildlife would respond to humans, dogs and coyotes as predators and that the level of the response would be relative to the perceived risk. Specifically, we expected humans to be the highest perceived risk, given that humans actively hunt deer throughout the region. Likewise, we expected humans with dogs to be perceived as a greater risk than humans without dogs given the additional perceived risk imposed by dogs. We expected unattended dogs and coyotes to be perceived as a similar level of risk given their similar size and less predictable movement patterns off trails.

2. Material and methods

2.1. Citizen science camera trap surveys

From 2012 to 2013, 376 trained volunteers deployed 1951 unbaited camera traps across 33 protected areas (15 hunted, 18 not hunted) in the Southeastern United States (Fig. 1). Surveys were predominantly done in summer and fall outside of the hunting season with only a few deployments (<5) extending into the main rifle season. All sites had similar hunting regulations including weapon type allowed and whether hunting with dogs was permitted (Appendix D). All wildlife species examined in this study are legally hunted in the study area and are common in the Southeastern United States with white-tailed deer thought to exist at the highest densities among mammal species in that area (Horsley et al., 2003; Kays et al., 2016). Coyotes are the largest predator in the region, however the similar-sized bobcats (*Lynx rufus*) are also present at some sites. We define "protected areas" as publicly owned and managed land protected from private development. Protected areas were large tracts of core forest from 4 km^2 to 1200 km^2 (average = 140 km^2) surrounded by a range of rural (<0.5 house/km^2) to urban (>1000 houses/km^2) densities of development (Theobald, 2005). Twenty protected areas required that dogs be leashed, nine did not require leashes and four prohibited pets completely (Fig. 1). Each individual camera is considered a "camera site", and these were set in groups of three (hearafter "transect"): on, near (50 m) and far

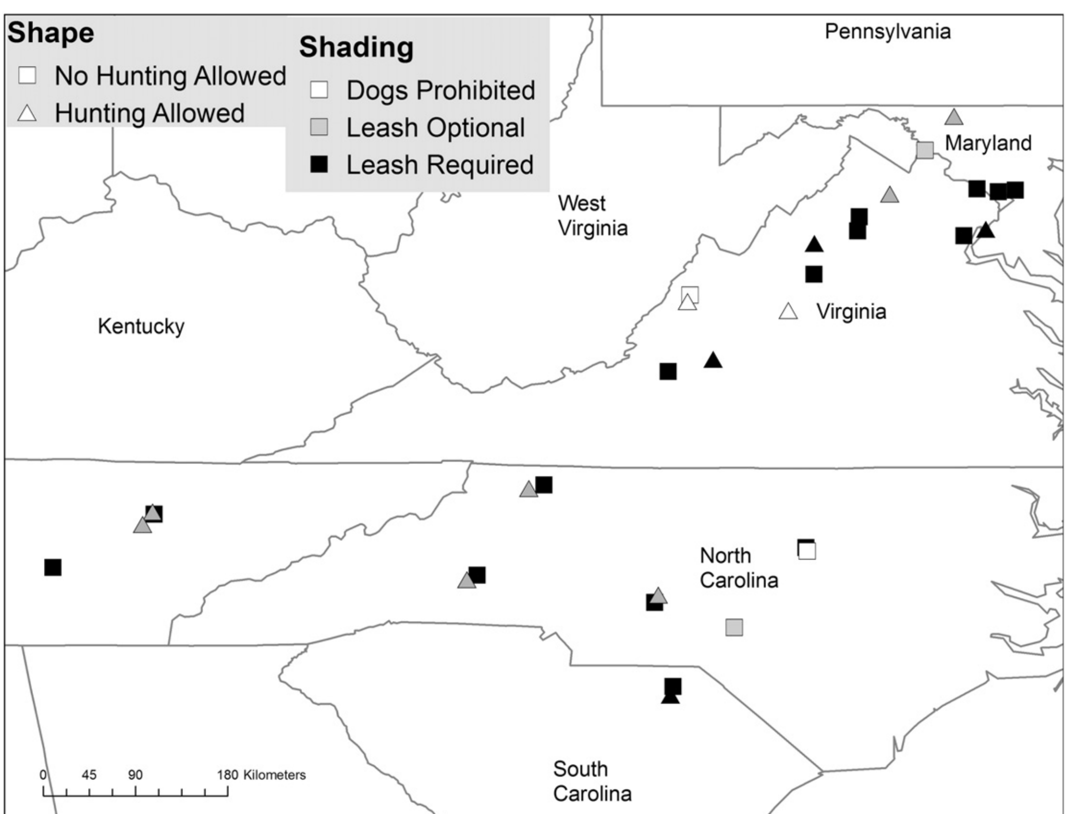

Fig. 1. Site map showing the 33 protected areas sampled and their dog and hunting regulations.

(200 m) from a hiking trail. Trail locations were chosen at random without regard for the distance to the trailhead. Associated 50 m and 200 m cameras were chosen at perpendicular Euclidean distances from the trail camera location and faced in the clearest direction to maximize detection distance. The direction from the trail was determined based on proximity to adjacent transects and accessibility (i.e. slope). Inappropriate off-trail locations (i.e. briar patches, steep slopes) were avoided and cameras were moved to a better location within 20 m of the original point. All adjacent cameras not within the same transect were spaced at least 200 m apart. Volunteers used Reconyx (RC55, PC800, and PC900, Reconyx, Inc. Holmen, WI) and Bushnell (Trophy Cam HD, Bushnell Outdoor Products, Overland Park, KS) camera traps equipped with an infrared flash and attached to trees at 40 cm above the ground and left them for three weeks before moving them to new locations. Cameras were not checked within that three-week period. Cameras recorded multiple photographs per trigger, at a rate of 1 frame/s, retriggering immediately if the animal was still in view. For analysis we grouped consecutive photos into sequences if they were <60 s apart, and used these sequences as independent records for subsequent analysis. We assessed the adequacy of this temporal independence using by-minute temporal autocorrelation functions in Program JMP (SAS, Cary, NC, USA) for each species at their top 10 most active sites (i.e. the sites most likely to have temporal autocorrelation). Initial species identifications were made by volunteers using customized software (eMammal.org) and all were subsequently reviewed for accuracy before being archived at the Smithsonian Digital Repository (McShea et al., 2016). We used the detection rate (the number of detections of a given species divided by the total number of camera-nights, hereafter "DR") to compare the relative activity levels of each species. Though not immune to issues of heterogeneity in detection probabilities, because sites were selected at random relative to animal movement, and not baited, DR is a valid comparison across our sites (Rowcliffe et al., 2013).

2.2. Dog distribution

To evaluate if off-trail dogs were accompanied by a human we examined all three cameras from the same transect that detected the off-trail dog to see if a human passed within 5 min. We used an ANOVA in Program JMP to test for an effect of leash laws on dog activity (DR and % of dogs that went off-trail) and leashing rate (coded from a subset of $n = 50$ randomly selected photos/protected area).

2.3. Spatial avoidance

We used two-species conditional occupancy models (Richmond et al., 2014) to assess deer, squirrel and raccoon spatial avoidance of each predator (humans without dogs, attended dogs, unattended dogs, coyotes) using Package RMark in Program R (Team, 2011). We included covariates to account for variation in detection and occupancy due to habitat and weather (Appendix A). We diagnosed univariate correlations between covariates using a Pearson correlation matrix, and omitted variables correlated >0.60. All continuous variables were mean-centered. We tested housing density, edge and the amount of forest at two scales, 5 km and 250 m, that most closely reflected reported home range sizes of each species (Koprowski, 1994; Lotze and Anderson, 1979; Walter et al., 2009) and protected area size. We ran a suite of 20 detection probability models for each species except the human predators where we removed People_site as a covariate, then picked the most parsimonious model of each within the top three QAIC points (Burnham and Anderson, 2002) to use in our occupancy models (Appendix B). We ran a suite of 27 occupancy models for each species and used the top models in our two-species models (Appendix B). We compared four 2-species models for each predator/prey combination using QAIC, including models incorporating trail as a categorical grouping covariate, models incorporating the top single-species models and models including DR covariates for each predator not explicitly being modeled (e.g. coyote DR was included in the attended dog models) to account for possible interactions between predators that may influence prey site occupancy (Appendix C).

2.4. Temporal avoidance

We used the time series of detections from a given camera to test the relative avoidance of a site by prey after the passage of a predator. We call these measures Avoidance-Attraction Ratios (AAR), and they can be created either by comparing the time interval after/before a predator passes (T2/T1) or with/without the passage of a predator (T4/T3, Fig. 2). T1 is the length of time between an initial prey passage and the predator passage and T2 is the length of time between the passage of a predator and a subsequent prey passage (Fig. 2). T3 is the average length of time between successive prey detections without a predator in the middle while T4 is the same measure with a predator between (Fig. 2). Because we calculate these values for each camera site separately, these ratios are robust to differences in detection probability between predator and prey species since the passage rates are a relative, not absolute, measure of the use of a site.

T2/T1 could be influenced both by the avoidance of the prey and the attraction of the predator, while T4/T3 is influenced solely by the avoidance of the predator by the prey. Where multiple predators of the same species passed consecutively before the next deer detection, the total time from the first predator detection to the next prey detection was calculated for T2 to account for increases in scent deterring prey. We considered interactions where only one type of predator appeared between successive prey detections in order to avoid potential confounding effects of multiple predator types. We compared T2/T1 ratios between perceived predators for each species using the Wilcoxon method in Program JMP. We tested the effect of hunting on the magnitude of the log transformed T2/T1 ratio on and off trails for each perceived predator using t-tests in Program JMP.

2.5. Deer vigilance

To evaluate if deer perceive dogs as a threat, we analyzed the vigilance behavior of solitary deer in a subset of approximately 100 randomly selected sequences in every protected area. For each sequence of a solitary deer, we recorded whether the individual was exhibiting vigilant (head up, above shoulder), neutral (head below shoulder,

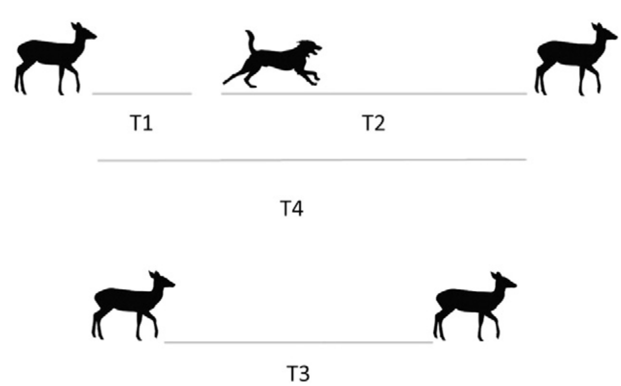

Fig. 2. Procedure for using data from a single camera trap to calculate Avoidance-Attraction Ratios (AARs) estimating within-site temporal avoidance or attraction of two species. T1 is the time from the initial deer detection to the first subsequent predator detection. T2 is the time from that first predator detection to the subsequent deer detection. If multiple predators pass before the next deer T2 is still taken from the first predator. T4 is the sum of T1 and T2 and represents the time between successive deer detections with a predator detection between them, while T3 is the time between successive deer detections without a predator between them. Values >1 for T2/T1 or T4/T3 suggest nonrandom movement between the two species indicating that the prey is avoiding the area after the passage of a predator. Attraction of a predator to a prey could also result in high T2/T1 ratios, but would result in lower ratios of T4/T3.

above knee), or non-vigilant behavior (head below knee) (Lashley et al., 2014). To ensure a more accurate representation of the behavior of each individual, we only scored individuals that had at least five photos within a sequence. If a deer looked at the camera we stopped scoring the sequence to exclude data potentially biased from the presence of the camera. We used a Wilcoxon signed-rank test in Program JMP to compare deer vigilance between sites on and off trails that were and were not used by three classes of "predator": humans without dogs (dogs not detected within 5 min, human not holding a leash), attended dogs (dogs <5 min from a human, leashed or not), unattended dogs (dogs without humans) and coyotes.

3. Results

3.1. Dog, human and wildlife distribution

We obtained 52,863 detections of native wildlife, 162,418 detections of humans and 23,332 detections of domestic dogs with 42,874 camera nights of survey effort across 1951 locations in 33 protected areas. Only 7% of site examined showed temporal autocorrelation >25%. White-tailed deer was the most commonly detected native wildlife species overall (0.64/day) followed by eastern gray squirrel (0.25/day) and northern raccoon (0.08/day). Most dogs (99%) were detected on-trails, where they were more commonly detected than the most common native predator, coyotes (coyote: 0.10/day, dog: 1.58/day). Dogs were less frequently detected off-trails (0.00 dogs/day) than coyotes (0.02/day) but were still more common off-trails than red foxes (*Vulpes vulpes*) (0.006/day), bobcats (0.004/day) and gray foxes (*Urocyon cinereoargenteus*) (0.003/day) (Fig. 3). Most protected areas (88%) had at least some off-trail dogs. The only species examined that were caught actively being chased on camera were white-tailed deer being chased by unattended dogs (recorded 5 times) or coyotes (recorded 4 times). Three incidents of unattended dogs chasing deer were of packs of 2–4 dogs, the remaining incidents were of what appeared to be solitary individuals.

Most (82%) off-trail dogs were detected <5 min from a nearby human. Humans were detected off trails very rarely (0.60% of all human detections). Therefore, we assumed that off-trail dogs not within 5 min of a human on the trail (or off the trail) were unattended. Across all detections, 97% of dogs were accompanied by humans and most unaccompanied dogs were on-trails (87%). Twenty-three percent of unattended dogs were running in packs of 2–4 individuals, likewise 24% of attended dogs were in groups of 2–8. Most dogs were off-leash (on-trail: 60%; off-trail: 84%). Leash laws reduced the frequency of unleashed dogs by 21% (55% with leash law, 76% without). Only 0.80% of dogs were photographed at night, and only 16 dogs were documented running off-trail at night without a leash. Leashing rates decreased farther from the trailhead, suggesting that owners may have let their dogs off leash after their walk began.

We detected dogs in all protected areas sampled, even where dogs were prohibited. Areas prohibiting dogs had 16 times fewer dogs per day than sites allowing dogs ($F = 10.28$, $df = 1895$, $p < 0.0001$), but a higher percentage (13%) of those dogs went off-trail ($t = 7.61$, $df = 280$, $p = 0.0006$, Fig. 4). Dog detections were strongly positively correlated with the rate that humans without dogs were detected, on and off-trails (On: $F = 1029.73$, $df = 665$, $p < 0.001$, Off: $F = 454.96$, $df = 1299$, $p < 0.0001$). However, off-trail dog detections were not significantly correlated with on-trail human detection rate ($F = 0.31$, $df = 648$, $p = 0.58$). Human DR was highest in areas where leashes were required (mean = 8.87, SE = 2.25) and lowest where dogs were prohibited (mean = 3.70, SE = 2.98).

3.2. Spatial avoidance

Across all sites, occupancy was highest for deer followed by gray squirrel and raccoon. The amount of daily cloud cover explained the most variation in detection probability for coyote, raccoon, attended dogs, humans without dogs and squirrels (Appendix B). Measures of edge explained the most variation in occupancy for attended dogs, humans without dogs, deer and squirrels (Appendix B). Our two-species occupancy models showed no significant spatial avoidance, however all prey species tended to avoid trail sites with unattended dogs. The probability of raccoon site occupancy was actually higher where coyotes were present (Fig. 5). A similar increase in occupancy was found for squirrels where unattended dogs were present off trails (Fig. 5).

3.3. Temporal avoidance

All species temporally avoided humans with and without dogs more than any other predator, with the exception of northern raccoons, which temporally avoided coyotes more than humans without dogs. AAR avoidance was significantly stronger for attended dogs than the other predators for all species and ranged from 7 to 3 times higher (eastern gray squirrel and white-tailed deer respectively) than any other predator (Fig. 6). Likewise, AAR avoidance was stronger over all species for humans without dogs than unattended dogs (7–5 times stronger, squirrel and raccoon respectively). AAR avoidance was 3 times stronger for humans without dogs than coyotes for all species except raccoon (Fig. 6). AAR avoidance was weakest for unattended dogs for all species (2–10 times weaker, deer/squirrel and raccoon respectively) but this was only statistically significant for deer (Fig. 6). Deer living in protected

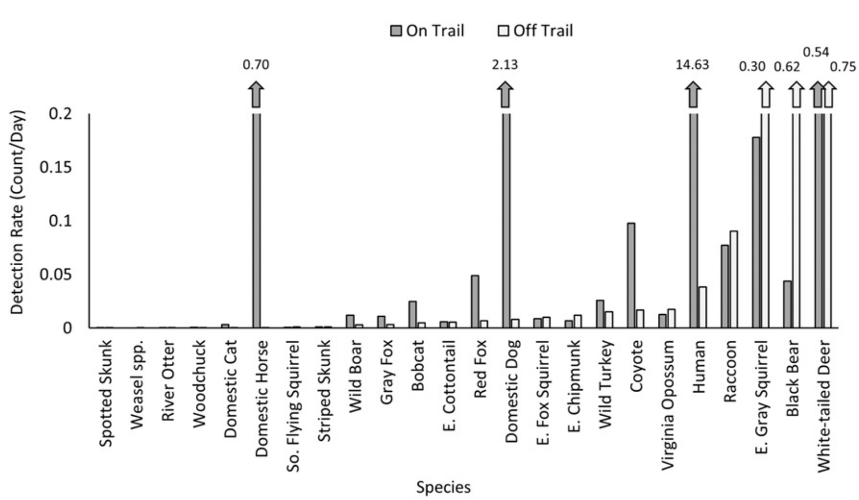

Fig. 3. Detection rates (count/day) for all species detected over all cameras sorted by highest off trail detection rate.

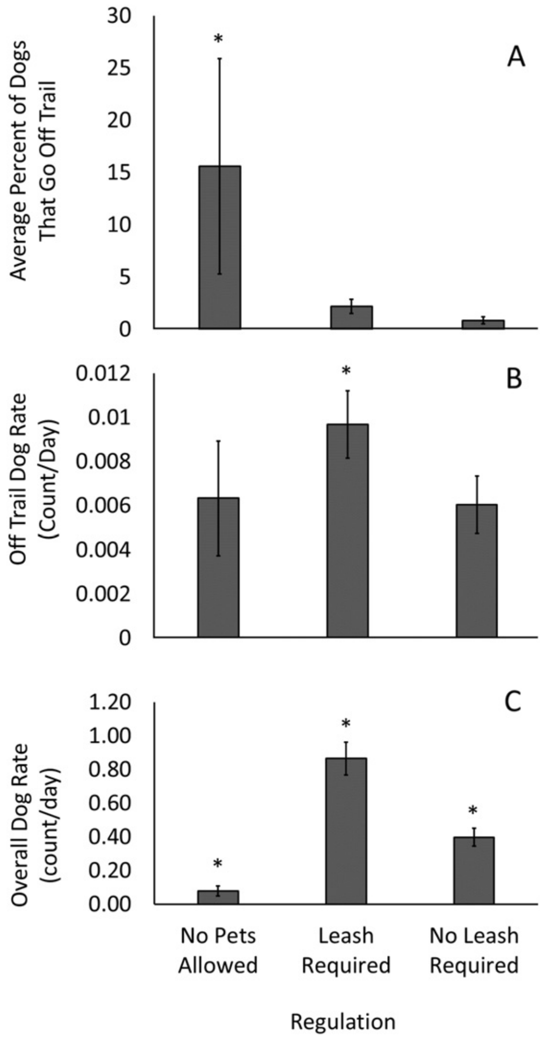

Fig. 4. Leash laws in relation to the (A) average percent of dogs off-trail, (B) average off-trail dog detection rate and (C) average dog detection rate for on and off-trail dogs. Data came from 145 camera sites in areas with no pets allowed, 302 with no leash required and 785 with leashes required. Error bars represent the standard error of the mean, and * indicates a significant difference from the other two regulation categories.

areas with recreational hunting had lower temporal avoidance of attended dogs by (on trails: $t = -3.70$, $p = 0.0002$, off trails: $t = -2.13$, $p = 0.04$). Squirrels also showed significantly less temporal avoidance of on-trail attended dogs in hunted areas (2 times less, $t = -2.44$, $p = 0.02$). We found no other significant differences in temporal avoidance between hunted and unhunted areas.

3.4. Deer vigilance

On average, deer were vigilant 22% of the time, head-down 44% of the time and head intermediate 34% of the time. Deer vigilance was 3% higher at sites where coyotes and humans without dogs were also detected and 2% higher at sites where attended dogs were also detected, though not all of these differences were significant (Table 1). Vigilance was 1% higher at sites without unattended dogs, though this difference was not statistically significant (Table 1). There were no significant differences in vigilance when on and off-trail sites were considered separately (Table 1).

4. Discussion

Our large scale camera trap survey showed that humans and dogs are the two most common mammals using protected areas across the region, but that their activity is highly concentrated along hiking trails. Our analysis of behavioral responses by wildlife to humans and dogs found little significant spatial avoidance, small increases in vigilance behavior, and a variable but important temporal avoidance. These metrics allow us to evaluate the ecological impact of humans and dogs within the risk-disturbance framework (Frid and Dill, 2002) by comparing them with a natural predator (coyotes). Contrasting these factors across parks with different regulations about dogs and hunting also allows us to evaluate the effectiveness of these management decisions on the wildlife-human conflict associated with outdoor recreation.

Of our three approaches to quantify disturbance of wildlife, the measures of temporal avoidance showed the most significant effects. Humans, as predicted, were the highest perceived risk, with all three prey species avoiding sites longest after people passed. Dogs by themselves had the lowest perceived risk in our comparisons. However, temporal avoidance was greatest for people accompanied by a dog. This compounding effect of dogs on the disturbance of wildlife has also been found for birds (Banks and Bryant, 2007; Weston et al., 2014) and other mammals (Mainini et al., 1993; Miller et al., 2001).

Our assessment of wildlife disturbance through spatial avoidance or increased vigilance showed few significant impacts. All species tended to spatially avoid unattended dogs on trails, but the results were not statistically significant. Deer increased their vigilance at sites with humans alone, but not at sites with dogs or coyotes. In a separate analysis of vigilance data incorporating intensity of human activity rather than simple presence/absence, we found that vigilance decreased as human activity increased (Schuttler et al. 2016, unpublished data). This difference is likely due to habituation in areas of heavy human traffic, something we did not examine in detail in this study (Recarte et al., 1998).

The three prey species in our study showed no significant spatial avoidance of unattended dogs, lower temporal avoidance in comparison with other predators, and no changes in deer vigilance related to dog activity. These minor impacts contrast a large body of work showing that free-ranging dogs are more detrimental to wildlife than leashed dogs (Hughes and MacDonald, 2013; Silva-Rodríguez and Sieving, 2012; Weston and Stankowich, 2014). We suspect that this difference is a reflection of the overall rarity of free ranging dogs in the protected areas we surveyed. Given that 99% of dogs are on the trails and 97% are with people, only a small fraction of the interactions between dogs and wildlife will be with truly free ranging dogs. Where these interaction occur, it seems that packs of free ranging dogs may present more of a threat than single dogs. Packs were responsible for at least 60% of recorded interactions with deer in our study, however the majority of dogs did not appear to be in packs and most were attended by people. We suspect that prey species in this region have adjusted their disturbance response to dogs in general to reflect the relatively low risk posed by an on-trail dog walking with its owner.

We expected unattended dogs and coyotes to be similar in perceived risk by prey given their similar size and unpredictable off-trail movement, however, all prey species temporally avoided coyotes more than unattended dogs and showed no significant spatial avoidance of either species. Indeed, spatially raccoons had higher occupancy at sites also occupied by coyotes which could indicate similar habitat preferences or active pursuit by coyotes. We found a similar result for squirrels and unattended dogs off trails. Despite evidence that unattended dogs and coyotes both pursue deer, deer showed no temporal avoidance of either species, no changes in vigilance and relatively low temporal avoidance. Since the extirpation of wolves from the Southeast in the mid-1900s, deer have no predators to regulate their populations, except human hunters (Wallach et al., 2015). Coyotes are a recent arrival to the Southeast and it is unclear whether deer are responding to coyotes as an apex predator in the same way they would wolves. Coyotes do depredate deer, although typically fawns rather than adults in the Southeast (Kilgo et al., 2010). The minimal reactions of deer found in our study suggest that neither coyotes nor humans are perceived as a strong threat by adult deer.

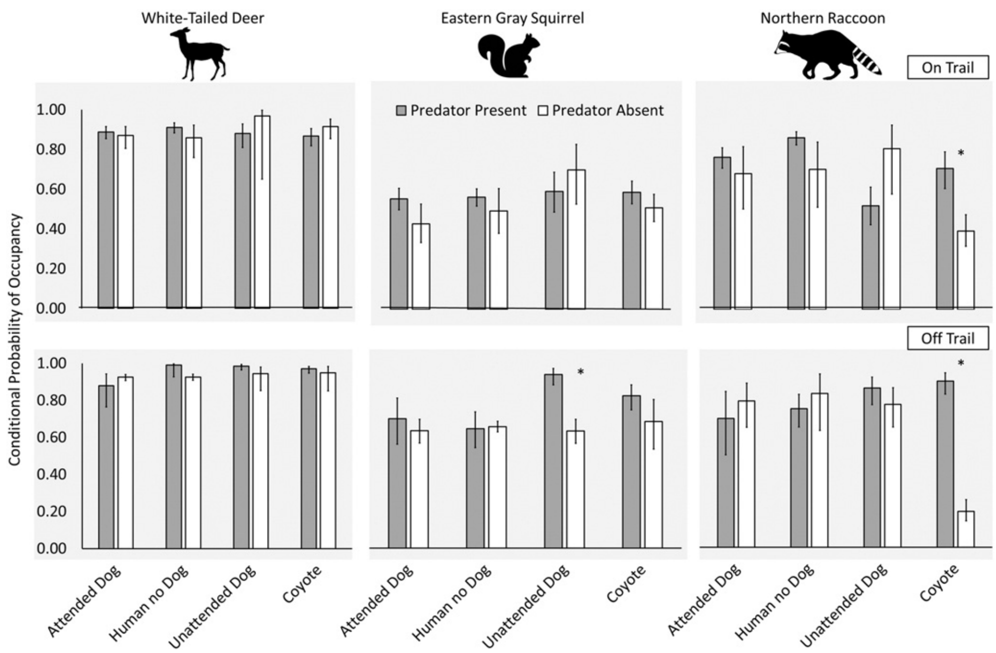

Fig. 5. Conditional probability of white-tailed deer, eastern gray squirrel and raccoon occupancy in the presence and absence of different potential predators on and off trails. Error bars show 95% confidence interval, * indicates a significant difference in occupancy between predator presence and absence based on non-overlapping 95% confidence intervals.

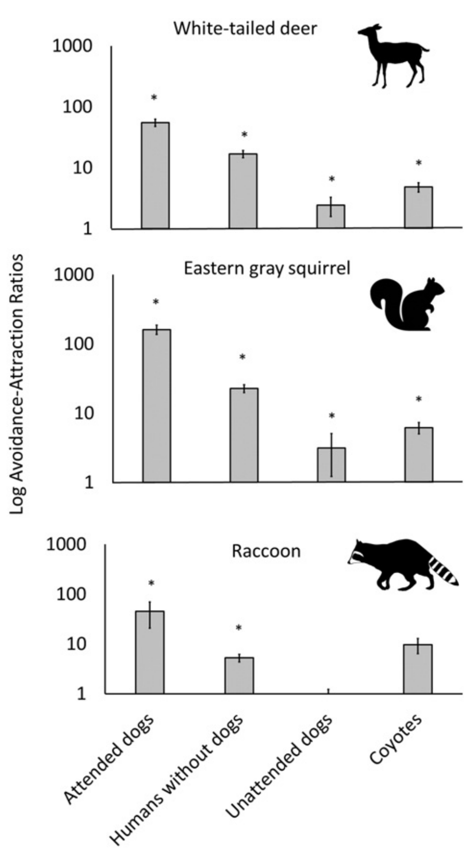

Fig. 6. Temporal avoidance of an area by three prey species after the passage of four different potential predators. Avoidance-attraction ratios (AAR) larger than 1 show avoidance, with larger values indicating longer times before revisiting a site. (*) denotes a significant difference ($\alpha = 0.05$) in AAR from the other three predators. Humans with and without dogs were avoided more than coyotes or unattended dogs by all three species. Only raccoons showed significantly higher avoidance of coyotes compared to humans without dogs.

Our report is the first large scale assessment of dogs in protected areas in the United States, offering the best estimate of what proportion of dogs are free ranging in the region and the effect of management regulations on dog owner behavior. Dogs were abundant in each of the 33 protected areas sampled, and often were the most commonly detected nonhuman mammal. We found widespread disregard for leash laws in parks, especially when hikers got farther away from trailheads where enforcement was more likely. This rate was lower than smaller nearby parks (Leung et al., 2015), but consistent with past studies of compliance from around the world (Weston et al., 2014). Despite this blatant disregard for leashing laws, most dogs were still found on the trail walking with their owners, and thus were not a strong source of disturbance to the region's wildlife (Forrest and St. Clair, 2006; Reed and Merenlender, 2011).

Few studies have investigated the benefits of dog management on reducing impacts of pet recreation on wildlife. Past studies of dog management regulations have found no effect on wildlife diversity and abundance (Forrest and St. Clair, 2006; Reed and Merenlender, 2011), however management that increases leashing rates would conceivably decrease indirect effects of disturbance on fitness (Weston et al., 2014). Despite the general disregard for management regulations, requiring leashes did increase leashing rate by 21%. Likewise, rules prohibiting dogs decreased dog activity by 87% and decreased people walking dogs off trails by 90%. This shows that dog management regulations do help control dog behavior and can succeed in reducing the impact of dogs.

We predicted that protected areas that allowed hunting would have animals more easily disturbed by recreational hikers, since humans would be real threats to wildlife, at least during hunting season. To the contrary, we found that deer and squirrels living in areas that allowed hunting had weaker temporal avoidance of attended dogs. We found no significant effect of hunting for any other predator or prey species, consistent with our earlier study of the effects of recreation on wildlife (Kays et al., 2016). These results are contrary to other studies which have shown increased flight responses to people in hunted populations of ungulates versus unhunted populations (Stankowich, 2008).

Table 1
Deer vigilance compared at sites (on trails, off trail and combined) where potential predator species were and were not detected. Predators were humans without dogs, attended dogs (dogs < 5 min from a human, leashed or not), unattended dogs (dogs without humans) and coyotes. Comparisons were done using a Wilcoxon signed-rank test. Significant differences are in bold.

Predator	Effect size (with-without)	n (with, without)	SE (with, without)	χ^2	df	p
On trail						
Attended dog	−0.11%	(170, 67)	(1.54%, 2.69%)	0.03	1	0.87
Human without dog	2.55%	(208, 29)	(1.45%, 3.41%)	0.22	1	0.64
Unattended dog	0.42%	(50, 187)	(3.33%, 1.45%)	0.12	1	0.73
Coyote	−1.96%	(130, 107)	(1.59%, 2.27%)	0.01	1	0.91
Off trail						
Attended dog	−6.81%	(38, 501)	(2.46%, 0.96%)	3.09	1	0.08
Human without dog	2.42%	(49, 490)	(2.98%, 0.96%)	0.98	1	0.32
Unattended dog	−3.62%	(21, 518)	(3.22%, 0.94%)	0.11	1	0.75
Coyote	2.81%	(98, 441)	(2.11%, 1.01%)	2.09	1	0.15
Combined						
Attended dog	−0.08%	(208, 568)	(1.36%, 0.90%)	0.19	1	0.66
Human without dog	**2.66%**	(257, 519)	(1.30%, 0.92%)	4.03	1	0.04
Unattended dog	0.09%	(71, 705)	(2.54%, 0.79%)	0.01	1	0.91
Coyote	1.51%	(228, 548)	(1.28%, 0.92%)	3.14	1	0.08

5. Conclusions

We found that dogs are the most common non-human mammal using protected areas in the Eastern USA, but that their activity is highly concentrated along trails. We found relatively little spatial or behavioral response of prey species to dogs or humans, but temporal avoidance suggests that humans are perceived as a greater risk by wildlife relative to unattended dogs and coyotes. Furthermore, dogs walking with humans increase the perceived risk, causing wildlife to avoid an area for a greater amount of time than in response to humans alone. Free-ranging dogs were not perceived as a high risk by wildlife, contrasting strong negative ecological effects found in other studies of free-ranging dogs (Vanak and Gompper, 2009; Vanak et al., 2009; Young et al., 2011). These results show how the responsible control of dog behavior by their owners can minimize disturbance of wildlife. We also found that regulations by protected area managers succeed in reducing the impact of dogs; prohibiting dogs in protected areas reduced their use of an area by a factor of 10 while leash laws increased leashing rates by 21% (45% leashed with leash law, 24% without). Although millions of dogs use natural areas each year, regulations enacted by protected areas combined with responsible management of dog behavior by pet owners work together to reduce the ecological impact of dogs and increase outdoor enjoyment by hikers and their pets.

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Appendix A. Covariates used for occupancy modeling

Covariates	Shorthand	Units	Source
Detection probability			
Cloud cover	Cloud	Percent, daily	NCEP-DOE surface total cloud cover entire atmospheric column
Temperature	Temp	Celsius, daily	ECMWF interim full daily SFC temperature (2 m above ground)
Precipitation	Precip	Milliliters, daily	NCEP NARR precipitation rate at surface
Year	Year	Year	
Canopy cover	NDVI	Percent, site-average	MODIS land terra vegetation indices 1 km monthly NDVI
Hiker count	People	Count/site	
Hunting	Hunting	Yes/no	
Detection distance	Det_dist	Meters, site specific	
Occupancy			
Housing density (5 km radius)	HDens_5 km	Houses/km^2	Silvis housing density dataset
Large core forest (5 km radius)	LC_5 km	Percent	USGS GAP landcover dataset
Edge (5 km radius)	Edge_5 km	Percent	USGS GAP landcover dataset
Housing density (250 m radius)	HDens_250 m	Houses/km^2	Silvis housing density dataset
Large core forest (250 m radius)	LC_250 m	Percent	USGS GAP landcover dataset
Edge (250 m radius)	Edge_250 m	Percent	USGS GAP landcover dataset
Hunting	Hunting	Yes/no	
Distance to nearest trailhead	Trailhead	Meters	
Latitude × longitude	LatbyLong	Decimal degrees	
On or off trail	Trail	Categorical group	

Appendix B. Single-species occupancy model selection tables. Detection model selection was done using the most parameterized occupancy model. Because of high overdispersion, all model selection was done using QAIC

Detection models attended dog	df	Neg2LnL	QAIC	Delta QAIC
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + hunting + trail)	8	15,827.39	2374.83	0
p(~Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + trail)	9	15,816.9	2375.27	0.44
p(~NVDI_site + Precip + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	15,792.61	2375.65	0.82
p(~Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	15,827.39	2376.83	2
p(~Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	15,816.9	2377.27	2.44
p(~Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	15,866.5	2380.66	5.83
p(~Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	15,866.5	2382.66	7.83
p(~1)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	7	15,897.32	2383.25	8.42
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	15,873.11	2383.64	8.81
p(~Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	15,897.32	2385.25	10.42
Occupancy models attended dog				
p(~Cloud)Psi(~Trailhead + Hunting)	5.00	16,840.34	1711.13	0.00
p(~Cloud)Psi(~Edge_5 km + Hunting)	5.00	16,848.77	1711.99	0.85
p(~Cloud)Psi(~Edge_5 km)	4.00	16,871.44	1712.28	1.14
p(~Cloud)Psi(~Edge_250 m)	4.00	16,874.50	1712.59	1.45
p(~Cloud)Psi(~Hunting)	4.00	16,910.15	1716.19	5.05
p(~Cloud)Psi(~1)	3.00	16,935.80	1716.78	5.64
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting)	8.00	16,844.84	1717.59	6.45
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting)	8.00	16,847.26	1717.83	6.70
p(~Cloud)Psi(~HDens_5 km + Hunting)	5.00	16,907.00	1717.87	6.73
p(~Cloud)Psi(~HDens_5 km)	4.00	16,927.12	1717.90	6.77
p(~Cloud)Psi(~LC_5 km + Hunting)	5.00	16,908.70	1718.04	6.91
p(~Cloud)Psi(~HDens_250 m + Hunting)	5.00	16,908.97	1718.07	6.93
p(~Cloud)Psi(~LC_250 m + Hunting)	5.00	16,910.08	1718.18	7.04
p(~Cloud)Psi(~HDens_250 m)	4.00	16,933.26	1718.52	7.39
p(~Cloud)Psi(~LC_5 km)	4.00	16,933.35	1718.53	7.40
p(~Cloud)Psi(~LatbyLong)	4.00	16,935.29	1718.73	7.59
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting + Trailhead)	9.00	16,836.69	1718.77	7.63
p(~Cloud)Psi(~LC_250 m)	4.00	16,935.78	1718.78	7.64
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting + Trailhead)	9.00	16,838.32	1718.93	7.80
p(~Cloud)Psi(~LC_5 km + HDens_5 km + Hunting)	6.00	16,906.93	1719.86	8.73
p(~Cloud)Psi(~LC_5 km + HDens_5 km)	5.00	16,927.11	1719.90	8.77
p(~Cloud)Psi(~LC_250 m + HDens_250 m + Hunting)	6.00	16,908.66	1720.04	8.90
p(~Cloud)Psi(~LC_250 m + HDens_250 m)	5.00	16,932.97	1720.49	9.36
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting)	7.00	16,905.64	1721.73	10.60
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Hunting)	7.00	16,907.83	1721.95	10.82
Detection models unattended dog				
p(~NVDI_site + People_site + Temp + Cloud + Precip + Year + Det_dist)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	14	2948.74	1946.15	0
p(~People_site + Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	2964.76	1946.58	0.42
p(~NVDI_site + People_site + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	2960.57	1947.85	1.7
p(~People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	2964.76	1948.58	2.42
p(~NVDI_site + People_site + Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	12	2960.57	1949.85	3.7
p(~NVDI_site + People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	2964.07	1950.13	3.97
p(~People_site + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	2970.97	1950.61	4.46
p(~People_site + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	2970.97	1952.61	6.46
p(~People_site)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	2979.42	1954.11	7.96
p(~People_site + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	2979.42	1956.11	9.96
p(~Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	2980.95	1957.11	10.96
p(~Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	2985.4	1958	11.85
p(~Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	2980.95	1959.11	12.96
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	2987.94	1959.65	13.5
p(~Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	2985.4	1960	13.85
p(~NVDI_site + Precip + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	2980.04	1960.51	14.36
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	2987.51	1961.37	15.22
p(~Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	2987.94	1961.65	15.5
p(~1)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	7	2996.35	1963.12	16.97
p(~Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	2996.35	1965.12	18.97
Occupancy models unattended dog				
p(~People_site + Temp)Psi(~LC_5 km)	5	3109.00	579.12	0.00
p(~People_site + Temp)Psi(~HDens_5 km)	5	3116.17	580.43	1.31
p(~People_site + Temp)Psi(~LC_5 km + HDens_5 km)	6	3106.31	580.62	1.51
p(~People_site + Temp)Psi(~LC_5 km + Hunting)	6	3106.73	580.70	1.58
p(~People_site + Temp)Psi(~1)	4	3133.72	581.64	2.53
p(~People_site + Temp)Psi(~HDens_5 km + Hunting)	6	3114.58	582.14	3.02
p(~People_site + Temp)Psi(~LC_5 km + HDens_5 km + Hunting)	7	3104.88	582.36	3.25
p(~People_site + Temp)Psi(~Hunting)	5	3128.26	582.64	3.53
p(~People_site + Temp)Psi(~LC_250 m)	5	3129.92	582.95	3.83

(*continued*)

Detection models attended dog	df	Neg2LnL	QAIC	Delta QAIC
p(~People_site + Temp)Psi(~HDens_250 m)	5	3131.50	583.23	4.12
p(~People_site + Temp)Psi(~Edge_5 km)	5	3131.92	583.31	4.19
p(~People_site + Temp)Psi(~Trailhead + Hunting)	6	3121.12	583.34	4.22
p(~People_site + Temp)Psi(~LatbyLong)	5	3132.51	583.42	4.30
p(~People_site + Temp)Psi(~Edge_250 m)	5	3132.87	583.49	4.37
p(~People_site + Temp)Psi(~LC_250 m + Hunting)	6	3124.96	584.04	4.92
p(~People_site + Temp)Psi(~HDens_250 m + Hunting)	6	3126.68	584.35	5.24
p(~People_site + Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting)	8	3104.84	584.35	5.24
p(~People_site + Temp)Psi(~Edge_5 km + Hunting)	6	3127.06	584.42	5.31
p(~People_site + Temp)Psi(~LC_250 m + HDens_250 m)	6	3128.69	584.72	5.60
p(~People_site + Temp)Psi(~LC_250 m + HDens_250 m + Hunting)	7	3124.15	585.89	6.77
p(~People_site + Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting)	9	3104.13	586.22	7.11
p(~People_site + Temp)Psi(~LatbyLong + LC_250 m + HDens_250 m + Hunting)	8	3123.57	587.78	8.67
p(~People_site + Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting + Trailhead)	10	3104.01	588.20	9.09
p(~People_site + Temp)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting)	9	3122.18	589.53	10.41
p(~People_site + Temp)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting + Trailhead)	10	3118.38	590.83	11.72
Detection models humans without dogs				
p(~Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	21,862.51	1951.67	0
p(~NVDI_site + Precip + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	21,818.95	1951.81	0.15
p(~Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	21,862.51	1953.67	2
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	21,916.92	1954.48	2.81
p(~Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	21,916.92	1956.48	4.81
p(~1)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	7	21,979.33	1958	6.33
p(~Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	21,956.74	1958	6.33
p(~Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	21,979.33	1960	8.33
p(~Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	21,956.74	1960	8.33
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	21,970.02	1961.17	9.51
Occupancy models humans without dogs				
p(~Cloud)Psi(~Edge_250 m)	4.00	23,152.54	2808.32	0.00
p(~Cloud)Psi(~Edge_5 km)	4.00	23,153.03	2808.38	0.06
p(~Cloud)Psi(~Trailhead + Hunting)	5.00	23,139.19	2808.70	0.39
p(~Cloud)Psi(~Edge_5 km + Hunting)	5.00	23,144.58	2809.36	1.04
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting)	8.00	23,136.01	2814.32	6.00
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting)	8.00	23,138.35	2814.60	6.28
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting + Trailhead)	9.00	23,132.50	2815.89	7.58
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting + Trailhead)	9.00	23,133.76	2816.05	7.73
p(~Cloud)Psi(~1)	3.00	23,247.03	2817.75	9.43
p(~Cloud)Psi(~Hunting)	4.00	23,237.01	2818.54	10.22
p(~Cloud)Psi(~HDens_5 km)	4.00	23,239.81	2818.87	10.56
p(~Cloud)Psi(~LC_5 km)	4.00	23,242.72	2819.23	10.91
p(~Cloud)Psi(~LC_250 m)	4.00	23,243.13	2819.28	10.96
p(~Cloud)Psi(~LatbyLong)	4.00	23,245.33	2819.54	11.22
p(~Cloud)Psi(~HDens_250 m)	4.00	23,245.82	2819.60	11.28
p(~Cloud)Psi(~HDens_5 km + Hunting)	5.00	23,233.12	2820.06	11.75
p(~Cloud)Psi(~LC_250 m + Hunting)	5.00	23,233.43	2820.10	11.78
p(~Cloud)Psi(~LC_5 km + Hunting)	5.00	23,233.58	2820.12	11.80
p(~Cloud)Psi(~HDens_250 m + Hunting)	5.00	23,236.41	2820.46	12.14
p(~Cloud)Psi(~LC_5 km + HDens_5 km)	5.00	23,239.28	2820.81	12.49
p(~Cloud)Psi(~LC_250 m + HDens_250 m)	5.00	23,242.72	2821.23	12.91
p(~Cloud)Psi(~LC_5 km + HDens_5 km + Hunting)	6.00	23,232.27	2821.96	13.64
p(~Cloud)Psi(~LC_250 m + HDens_250 m + Hunting)	6.00	23,233.32	2822.09	13.77
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting)	7.00	23,228.10	2823.46	15.14
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Hunting)	7.00	23,230.36	2823.73	15.41
Detection models coyote				
p(~Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	10,196.05	2384.25	0
p(~NVDI_site + People_site + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	10,179.65	2384.44	0.19
p(~People_site + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	10,202.14	2385.66	1.41
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	10,211.14	2385.75	1.5
p(~Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	10,196.05	2386.25	2
p(~NVDI_site + People_site + Temp + Cloud + Precip + Year + Det_dist)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	14	10,162.07	2386.36	2.11
p(~NVDI_site + People_site + Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	12	10,179.65	2386.44	2.19
p(~NVDI_site + Precip + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	10,188.83	2386.57	2.32
p(~People_site + Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	10,209.01	2387.25	3.01
p(~Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	10,219.27	2387.64	3.39
p(~People_site + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	10,202.14	2387.66	3.41
p(~Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	10,211.14	2387.75	3.5
p(~NVDI_site + People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	10,198.32	2388.77	4.53
p(~People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	10,209.01	2389.25	5.01
p(~Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	10,219.27	2389.64	5.39
p(~People_site)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	10,238.55	2392.11	7.86
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	10,230.07	2392.14	7.89

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Detection models attended dog	df	Neg2LnL	QAIC	Delta QAIC
p(~1)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	7	10,247.89	2392.28	8.03
p(~People_site + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	10,238.55	2394.11	9.86
p(~Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	10,247.89	2394.28	10.03
Occupancy models coyote				
p(~Cloud)Psi(~LC_250 m)	4.00	10,455.31	2434.42	0.00
p(~Cloud)Psi(~LC_250 m + Hunting)	5.00	10,448.26	2434.78	0.36
p(~Cloud)Psi(~Edge_250 m)	4.00	10,459.44	2435.37	0.96
p(~Cloud)Psi(~HDens_5 km + Hunting)	5.00	10,451.14	2435.45	1.03
p(~Cloud)Psi(~LC_250 m + HDens_250 m)	5.00	10,453.57	2436.01	1.60
p(~Cloud)Psi(~HDens_5 km)	4.00	10,464.24	2436.49	2.07
p(~Cloud)Psi(~LC_250 m + HDens_250 m + Hunting)	6.00	10,447.12	2436.51	2.10
p(~Cloud)Psi(~LC_5 km + HDens_5 km + Hunting)	6.00	10,448.11	2436.74	2.33
p(~Cloud)Psi(~LC_5 km + HDens_5 km)	5.00	10,462.27	2438.03	3.61
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Hunting)	7.00	10,446.03	2438.26	3.85
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting)	7.00	10,446.35	2438.34	3.92
p(~Cloud)Psi(~1)	3.00	10,480.97	2438.37	3.95
p(~Cloud)Psi(~Edge_5 km + Hunting)	5.00	10,464.12	2438.46	4.04
p(~Cloud)Psi(~Edge_5 km)	4.00	10,473.17	2438.56	4.15
p(~Cloud)Psi(~Hunting)	4.00	10,474.97	2438.98	4.56
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting)	8.00	10,444.08	2439.81	5.39
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting)	8.00	10,444.87	2439.99	5.58
p(~Cloud)Psi(~LC_5 km)	4.00	10,479.80	2440.10	5.68
p(~Cloud)Psi(~LatbyLong)	4.00	10,480.83	2440.34	5.92
p(~Cloud)Psi(~HDens_250 m)	4.00	10,480.95	2440.37	5.95
p(~Cloud)Psi(~Trailhead + Hunting)	5.00	10,473.09	2440.54	6.13
p(~Cloud)Psi(~LC_5 km + Hunting)	5.00	10,473.42	2440.62	6.20
p(~Cloud)Psi(~HDens_250 m + Hunting)	5.00	10,474.96	2440.98	6.56
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting + Trailhead)	9.00	10,441.87	2441.30	6.88
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting + Trailhead)	9.00	10,442.69	2441.49	7.07
Detection models white-tailed deer				
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	47,465.81	1944.46	0
p(~NVDI_site + People_site + Temp + Cloud + Precip + Year + Det_dist)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	14	47,392.05	1951.47	7.01
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	47,808.3	1956.36	11.9
p(~1)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	7	47,871.91	1956.94	12.48
p(~People_site + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	47,796.75	1957.89	13.43
p(~Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	47,808.3	1958.36	13.9
p(~People_site)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	47,859.5	1958.44	13.98
p(~Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	47,811.33	1958.48	14.02
p(~Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	47,871.91	1958.94	14.48
p(~Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	47,873.3	1959	14.54
p(~People_site + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	47,796.75	1959.89	15.43
p(~People_site + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	47,859.5	1960.44	15.98
p(~Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	47,811.33	1960.48	16.02
p(~People_site + Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	47,861.21	1960.51	16.05
p(~Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	47,873.3	1961	16.54
p(~NVDI_site + People_site + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	47,796.85	1961.9	17.44
p(~NVDI_site + Precip + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	47,807.59	1962.33	17.87
p(~People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	47,861.21	1962.51	18.05
p(~NVDI_site + People_site + Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	12	47,796.85	1963.9	19.44
p(~NVDI_site + People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	47,858.3	1964.39	19.93
Occupancy models white-tailed deer				
p(~Det_dist + Year)Psi(~Edge_250 m)	5.00	47,458.22	1952.59	0.00
p(~Det_dist + Year)Psi(~Edge_5 km)	5.00	47,460.07	1952.66	0.08
p(~Det_dist + Year)Psi(~HDens_5 km)	5.00	47,491.71	1953.96	1.37
p(~Det_dist + Year)Psi(~1)	4.00	47,544.16	1954.11	1.52
p(~Det_dist + Year)Psi(~Trailhead + Hunting)	6.00	47,448.15	1954.18	1.59
p(~Det_dist + Year)Psi(~Edge_5 km + Hunting)	6.00	47,455.36	1954.47	1.88
p(~Det_dist + Year)Psi(~LC_5 km)	5.00	47,505.93	1954.54	1.95
p(~Det_dist + Year)Psi(~HDens_250 m)	5.00	47,536.17	1955.78	3.19
p(~Det_dist + Year)Psi(~Hunting)	5.00	47,538.68	1955.88	3.29
p(~Det_dist + Year)Psi(~HDens_5 km + Hunting)	6.00	47,491.40	1955.95	3.36
p(~Det_dist + Year)Psi(~LatbyLong)	5.00	47,541.83	1956.01	3.42
p(~Det_dist + Year)Psi(~LC_250 m)	5.00	47,543.81	1956.09	3.50
p(~Det_dist + Year)Psi(~LC_5 km + Hunting)	6.00	47,500.26	1956.31	3.72
p(~Det_dist + Year)Psi(~LC_5 km + HDens_5 km)	6.00	47,504.52	1956.48	3.90
p(~Det_dist + Year)Psi(~HDens_250 m + Hunting)	6.00	47,531.77	1957.60	5.01
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting)	9.00	47,387.07	1957.67	5.09
p(~Det_dist + Year)Psi(~LC_250 m + HDens_250 m)	6.00	47,534.80	1957.72	5.13
p(~Det_dist + Year)Psi(~LC_250 m + Hunting)	6.00	47,538.27	1957.86	5.28
p(~Det_dist + Year)Psi(~LC_5 km + HDens_5 km + Hunting)	7.00	47,499.80	1958.29	5.70
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting)	8.00	47,473.23	1959.20	6.61
p(~Det_dist + Year)Psi(~LC_250 m + HDens_250 m + Hunting)	7.00	47,530.51	1959.55	6.96

(*continued*)

Detection models attended dog	df	Neg2LnL	QAIC	Delta QAIC
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting + Trailhead)	10.00	47,386.91	1959.67	7.08
p(~Det_dist + Year)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting)	9.00	47,443.87	1960.00	7.41
p(~Det_dist + Year)Psi(~LatbyLong + LC_250 m + HDens_250 m + Hunting)	8.00	47,528.72	1961.47	8.89
p(~Det_dist + Year)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting + Trailhead)	10.00	47,438.30	1961.77	9.18
Detection models northern raccoon				
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	16,809.33	1952.53	0
p(~Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	16,801.06	1953.58	1.05
p(~People_site + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	16,802.88	1953.79	1.26
p(~Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	16,809.33	1954.53	2
p(~Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	16,801.06	1955.58	3.05
p(~People_site + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	16,802.88	1955.79	3.26
p(~NVDI_site + People_site + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	16,786.32	1955.88	3.35
p(~NVDI_site + Precip + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	16,793.21	1956.67	4.14
p(~NVDI_site + People_site + Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	12	16,786.32	1957.88	5.35
p(~Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	16,856.81	1958	5.47
p(~1)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	7	16,883.99	1959.13	6.6
p(~People_site + Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	16,849.88	1959.2	6.67
p(~NVDI_site + People_site + Temp + Cloud + Precip + Year + Det_dist)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	14	16,766.11	1959.55	7.02
p(~Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	16,856.81	1960	7.47
p(~People_site)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	16,877.95	1960.44	7.91
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	16,860.9	1960.47	7.94
p(~Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	16,883.99	1961.13	8.6
p(~People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	16,849.88	1961.2	8.67
p(~People_site + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	16,877.95	1962.44	9.91
p(~NVDI_site + People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	16,846.99	1962.87	10.34
Occupancy models northern raccoon				
p(~Cloud)Psi(~HDens_5 km)	4.00	16,849.72	1952.70	0.00
p(~Cloud)Psi(~LC_5 km)	4.00	16,853.15	1953.10	0.40
p(~Cloud)Psi(~LC_5 km + HDens_5 km)	5.00	16,842.53	1953.87	1.17
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting)	7.00	16,809.86	1954.10	1.40
p(~Cloud)Psi(~1)	3.00	16,881.58	1954.38	1.68
p(~Cloud)Psi(~Edge_5 km)	4.00	16,866.11	1954.59	1.89
p(~Cloud)Psi(~LatbyLong)	4.00	16,866.36	1954.62	1.92
p(~Cloud)Psi(~Trailhead + Hunting)	5.00	16,849.09	1954.63	1.93
p(~Cloud)Psi(~HDens_5 km + Hunting)	5.00	16,849.63	1954.69	1.99
p(~Cloud)Psi(~LC_5 km + Hunting)	5.00	16,851.48	1954.90	2.20
p(~Cloud)Psi(~Edge_250 m)	4.00	16,870.36	1955.08	2.38
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting)	8.00	16,806.12	1955.67	2.97
p(~Cloud)Psi(~HDens_250 m)	4.00	16,875.96	1955.73	3.03
p(~Cloud)Psi(~LC_5 km + HDens_5 km + Hunting)	6.00	16,842.25	1955.84	3.14
p(~Cloud)Psi(~Hunting)	4.00	16,878.65	1956.04	3.34
p(~Cloud)Psi(~LC_250 m)	4.00	16,881.40	1956.36	3.66
p(~Cloud)Psi(~Edge_5 km + Hunting)	5.00	16,864.87	1956.45	3.75
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting + Trailhead)	9.00	16,801.20	1957.10	4.40
p(~Cloud)Psi(~HDens_250 m + Hunting)	5.00	16,874.02	1957.50	4.80
p(~Cloud)Psi(~LC_250 m + HDens_250 m)	5.00	16,875.86	1957.72	5.02
p(~Cloud)Psi(~LC_250 m + Hunting)	5.00	16,878.53	1958.03	5.32
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting)	8.00	16,834.99	1959.00	6.30
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting + Trailhead)	9.00	16,820.52	1959.33	6.63
p(~Cloud)Psi(~LC_250 m + HDens_250 m + Hunting)	6.00	16,873.91	1959.49	6.79
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Hunting)	7.00	16,858.75	1959.74	7.04
Detection models eastern gray squirrel				
p(~Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	30,429.77	1947.4	0
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	30,466.31	1947.72	0.32
p(~Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	30,429.77	1949.4	2
p(~People_site + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	30,462.97	1949.51	2.1
p(~Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	30,466.31	1949.72	2.32
p(~NVDI_site + People_site + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	30,423.85	1951.03	3.62
p(~NVDI_site + Precip + Temp + Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	30,426.38	1951.19	3.79
p(~People_site + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	30,462.97	1951.51	4.1
p(~NVDI_site + People_site + Temp + Cloud + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	12	30,423.85	1953.03	5.62
p(~NVDI_site + People_site + Temp + Cloud + Precip + Year + Det_dist)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	14	30,380.12	1954.26	6.85
p(~Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	30,644.19	1959	11.6
p(~People_site + Temp)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	30,642.14	1960.87	13.47
p(~Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	30,644.19	1961	13.6
p(~Det_dist + Year)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	30,670.21	1962.65	15.25
p(~People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	10	30,642.14	1962.87	15.47
p(~1)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	7	30,749.68	1963.69	16.28
p(~NVDI_site + People_site + Temp + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	11	30,626.26	1963.86	16.46

(continued on next page)

(*continued*)

Detection models attended dog	df	Neg2LnL	QAIC	Delta QAIC
p(~People_site)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	30,746.46	1965.48	18.08
p(~Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	8	30,749.68	1965.69	18.28
p(~People_site + Precip)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting + Trail)	9	30,746.46	1967.48	20.08
Occupancy models eastern gray squirrel				
p(~Cloud)Psi(~Edge_5 km)	4.00	30,391.63	1950.21	0.00
p(~Cloud)Psi(~Edge_5 km + Hunting)	5.00	30,389.77	1952.09	1.88
p(~Cloud)Psi(~Edge_250 m)	4.00	30,469.21	1955.17	4.96
p(~Cloud)Psi(~Trailhead + Hunting)	5.00	30,452.51	1956.10	5.89
p(~Cloud)Psi(~LatbyLong)	4.00	30,489.81	1956.48	6.27
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting)	8.00	30,369.33	1956.78	6.57
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Edge_5 km + Hunting + Trailhead)	9.00	30,357.48	1958.03	7.82
p(~Cloud)Psi(~1)	3.00	30,553.16	1958.53	8.32
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting)	8.00	30,404.02	1959.00	8.79
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Edge_250 m + Hunting + Trailhead)	9.00	30,380.66	1959.51	9.30
p(~Cloud)Psi(~HDens_5 km)	4.00	30,543.37	1959.91	9.70
p(~Cloud)Psi(~LC_250 m)	4.00	30,546.10	1960.08	9.87
p(~Cloud)Psi(~LC_5 km)	4.00	30,551.52	1960.43	10.22
p(~Cloud)Psi(~HDens_250 m)	4.00	30,552.71	1960.50	10.29
p(~Cloud)Psi(~Hunting)	4.00	30,553.12	1960.53	10.32
p(~Cloud)Psi(~LC_5 km + HDens_5 km)	5.00	30,531.26	1961.13	10.92
p(~Cloud)Psi(~HDens_5 km + Hunting)	5.00	30,543.04	1961.88	11.68
p(~Cloud)Psi(~LC_250 m + HDens_250 m)	5.00	30,544.34	1961.97	11.76
p(~Cloud)Psi(~LatbyLong + LC_5 km + HDens_5 km + Hunting)	7.00	30,482.94	1962.04	11.83
p(~Cloud)Psi(~LC_250 m + Hunting)	5.00	30,546.03	1962.08	11.87
p(~Cloud)Psi(~LatbyLong + LC_250 m + HDens_250 m + Hunting)	7.00	30,486.24	1962.25	12.05
p(~Cloud)Psi(~LC_5 km + Hunting)	5.00	30,551.44	1962.42	12.21
p(~Cloud)Psi(~HDens_250 m + Hunting)	5.00	30,552.69	1962.50	12.29
p(~Cloud)Psi(~LC_5 km + HDens_5 km + Hunting)	6.00	30,530.52	1963.08	12.88
p(~Cloud)Psi(~LC_250 m + HDens_250 m + Hunting)	6.00	30,544.33	1963.97	13.76

Appendix C. Two-species occupancy model selection tables. Single-species detection models were either the most parsimonious detection model within the top 3 QAIC points in Appendix B (p(top)), a trail-only model (p(Trail)) or a null model (p(.)). Single-species occupancy models were either the top models in Appendix B with the addition of predator and trail covariates (psi(topPredsTrail) or a trail-only model (psi(Trail)). Trail only models had only a categorical Trail covariate. Preds indicates that predator DR other than the one explicitly being modeled were included as covariates. Because of high overdispersion, all model selection was done using QAIC. When models did not converge (*), the next best model was used to generate Psi estimates

Deer-attended dog	df	neg2L	QAIC	Delta QAIC	Model did not converge
p(Trail)psi(Trail)	16	18,630.80	1894.21	0.00	*
p(.)psi(Trail)	11	19,509.97	1972.08	77.88	
p(top)psi(Trail)	19	19,377.41	1974.83	80.63	
p(top)psi(topPredsTrail)	27	19,249.04	1978.00	83.79	
Deer-human without dog					
p(Trail)psi(Trail)	16	18,962.43	1846.47	0.00	*
p(top)psi(Trail)	19	20,139.79	1965.13	118.66	
p(.)psi(Trail)	11	20,309.32	1965.35	118.88	
p(top)psi(topPredsTrail)	26	20,128.02	1978.00	131.53	*
Deer-coyote					
p(Trail)psi(Trail)	16	19,218.63	1904.93	0.00	
p(.)psi(Trail)	11	19,866.63	1958.08	53.15	
p(top)psi(Trail)	19	19,798.78	1967.47	62.54	*
p(top)psi(topPredsTrail)	26	19,773.45	1979.00	74.07	*
Deer-unattended dog					
p(Trail)psi(Trail)	16	15,298.25	1957.27	0.00	*
p(top)psi(topPredsTrail)	28	15,280.20	1979.00	21.73	
p(top)psi(Trail)	21	15,404.43	1980.63	23.36	
p(.)psi(Trail)	11	15,606.86	1986.11	28.84	
Squirrel-attended dog					
p(Trail)psi(Trail)	16	16,097.46	1905.70	0.00	*
p(top)psi(topPredsTrail)	24	16,555.41	1975.00	69.30	
p(top)psi(Trail)	16	16,720.94	1978.27	72.57	
p(.)psi(Trail)	11	16,902.77	1989.43	83.74	
Squirrel-human without dog					
p(Trail)psi(Trail)	16	16,379.07	1866.89	0.00	*
p(top)psi(Trail)	16	17,301.50	1970.23	103.34	
p(top)psi(topPredsTrail)	23	17,210.23	1974.00	107.11	

(continued)

Deer-attended dog	df	neg2L	QAIC	Delta QAIC	Model did not converge
p(.)psi(Trail)	11	17,467.47	1978.82	111.93	
Squirrel-coyote					
p(Trail)psi(Trail)	16	16,874.01	1933.70	0.00	
p(top)psi(Trail)	16	17,172.45	1967.33	33.63	
p(top)psi(topPredsTrail)	23	17,107.40	1974.00	40.30	
p(.)psi(Trail)	11	17,351.01	1977.45	43.76	
Squirrel-unattended dog					
p(top)psi(Trail)	18	12,995.25	1974.62	0.00	
p(top)psi(topPredsTrail)	25	12,910.68	1976.00	1.38	
p(Trail)psi(Trail)	16	13,056.16	1979.70	5.09	
p(.)psi(Trail)	11	13,262.15	2000.43	25.82	
Raccoon-attended dog					
p(Trail)psi(Trail)	16	13,549.90	1958.33	0.00	
p(top)psi(topPredsTrail)	24	13,561.62	1976.00	17.67	*
p(top)psi(Trail)	16	13,921.39	2011.15	52.81	
p(.)psi(Trail)	11	14,011.23	2013.92	55.59	*
Raccoon-human without dog					
p(Trail)psi(Trail)	16	13,721.70	1906.27	0.00	
p(top)psi(topPredsTrail)	23	14,137.05	1977.00	70.73	*
p(.)psi(Trail)	11	14,496.48	2002.09	95.83	*
p(top)psi(Trail)	16	14,431.41	2003.21	96.94	*
Raccoon-coyote					
p(Trail)psi(Trail)	16	14,312.47	1933.6	0.00	
p(.)psi(Trail)	11	14,635.66	1966.5	32.94	
p(top)psi(Trail)	16	14,571.67	1968	34.44	
p(top)psi(topPredsTrail)	23	14,497.55	1972.2	38.59	
Raccoon-unattended dog					
p(top)psi(topPredsTrail)	25	10,582.86	1960.8	0.00	*
p(top)psi(Trail)	18	10,705.76	1969	8.19	*
p(Trail)psi(Trail)	16	10,729.36	1969.3	8.45	*
p(.)psi(Trail)	11	10,864.22	1983.6	22.80	

Appendix D. List of protected areas surveyed and their characteristics

Name	Size (km^2)	Hunting weapons allowed	Dog hunting allowed?	Species hunted	Deer firearm season length (days)	Camera sites
C & O Canal National Historical Park	82	No Hunting				57
Carvins Cove Nature Reserve	51	No Hunting				65
Catoctin Mountain Park/Cunningham Falls State Park	44	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	15	72
Cheraw State Park	28	No Hunting				66
Fall Creek Falls State Park	105	No Hunting				68
Frozen Head State Natural Area	53	No Hunting				68
Frozen Head State Park Emory Tract	125	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	51	50
Gambrill State Park	4.5	No Hunting				27
George Washington National Forest	4289	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	15	55
Greenbelt Park	4.8	No Hunting				46
Harpers Ferry National Historical Park	15	No Hunting				36
Jefferson National Forest	2792	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	15	60
Lone Mountain State Forest	14	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	51	53
Mason Neck State Park and Wildlife Refuge	16	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	15	75
Morrow Mountain State Park	18	No Hunting				66
Prince William Forest Park	65	No Hunting				80
Rock Creek Park	11	No Hunting				112
Sandhills State Forest	189	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	92	66
Shenandoah National Park North	203	No Hunting				58
Shenandoah National Park Central	281	No Hunting				52
Shenandoah National Park South	315	No Hunting				55
South Mountains Gameland	88	Archery, Muzzleloader, Firearm	No	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	75	62

(continued on next page)

(*continued*)

Name	Size (km^2)	Hunting weapons allowed	Dog hunting allowed?	Species hunted	Deer firearm season length (days)	Camera sites
South Mountains State Park	405	No Hunting				60
Stone Mountain State Park	58	No Hunting				61
Thompson Wildlife Management Area	16	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	15	71
Thurmond Chatham Gameland	26	Archery, Muzzleloader, Firearm	No	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	75	61
Umstead State Park	23	No Hunting				69
Uwharrie National Forest	205	Archery, Muzzleloader, Firearm	No	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	75	68
Warm Springs Mountain TNC Reserve Hunted	69.4	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	15	60
Warm Springs Mountain TNC Reserve Not Hunted	56.3	No Hunting				65
Weymouth Woods-Sandhills Nature Preserve	3.70	No Hunting				58
Wintergreen Resort	44.5	Archery, Muzzleloader, Firearm	Yes	White-tailed deer (antlered and antlerless), coyote, raccoon, squirrel	15	60

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