Occupancy of Large Canids in Eastern North Carolina—A Pilot Study

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Abstract: We used camera traps to estimate detection and occupancy of radio-collared and non-collared red wolves, coyotes, and red wolf-coyote hybrids (*Canis rufus, C. latrans,* and *C. rufus* × *C. latrans*) in Hyde County, North Carolina. This pilot study was to determine these variables among species and compare them between private and public lands. Large canids occurred throughout the public lands sampled, but occupancy of radio-collared individuals was low (0.41). Estimated occupancy of large canids throughout the study area was 0.74 with an estimated detection of 0.05. Occupancy of non-collared canids was twice that of radio-collared canids, but detection was similar. Results of these pilot efforts suggest that our sample sizes (i.e., number of cameras) were too low. Because of low sample sizes and low detection rates, additional research is needed to fine-tune occupancy rates within and among species and land classifications and thereby provide a landscape-scale perspective on the distribution, and potential implications, of large carnivores in southeast coastal landscapes. Detailed recommendations for continuing research include, among others, increased distribution, density, and duration of camera observation collections.

Key words: *Canis rufus, C. latrans,* and *C. rufus* × *C. latrans*, red wolf, coyote, canid, carnivore management, demography, North Carolina

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The red wolf (*Canis rufus*) once occupied diverse habitat types throughout their historical range in the eastern and south-central United States. Populations were decimated throughout the 20th century due to intensive predator control programs and loss of habitat. As the red wolf was being extirpated from its historical range, the coyote (*Canis latrans*), once restricted to the west and midwest regions, started to expand its range eastward (Novak 2002). This expansion may have also been due to the eradication of the gray wolf (*Canis lupus*), which reduced competitive pressures and opened up a niche for the coyotes to fill. Human development and agriculture further altered the landscape and created additional coyote habitat (Gompper 2002). Since then, coyotes have expanded its range over the entire United States (Gese et al. 2008). Hybridization between the two species has been a factor in further diminishing red wolf populations (Nowak 2002). By 1972, the red wolf's range was reduced to a small region in southeastern Texas and southwest Louisiana (Parker 1987). A Red Wolf Recovery Plan was initiated and the red wolf was officially listed as endangered in 1975. It became apparent that the only way to reestablish this population was to capture the remaining red wolf population and place them in a captive breeding program. After the red wolf breeding program was well underway, the U.S. Fish and Wildlife Service (USFWS) turned its attention to the idea of reintroducing red wolves into favorable areas within the species home range. In 1986, four pairs of red wolves were reintroduced to the Alligator River National Wildlife Refuge (ARNWR) located in Dare County, North Carolina. A nonessential experimental designation was given to the released wolves to provide protection under the Endangered Species Act (ESA) (Parker 1987). The current estimated population of red wolves is 50–75 in the wild and only a few breeding pairs still remain on ARNWR, the rest have moved onto private land. Figure 1 (USFWS 2014) shows the potential range and general distribution of monitored breeding red wolf pairs and sterile mixed pairs in the red wolf recovery area as of 2014. This map would look different today, but it is a good representation of how these animals are spread throughout the recovery area. Having red wolves on private land is one reason the Red Wolf Recovery Program has been controversial and includes many stakeholders including private landowners, state, and federal agencies. Coyote populations have largely increased in North Carolina. Coyote trapping and hunting harvest reports in the coastal region of North Carolina was 11, 361 for the 2010–1011 season (North Carolina Wildlife Resources Commission 2012). This report shows the prevalence of coyotes on the landscape in eastern North Carolina.

Coyotes and red wolves seem to be fulfilling the same niche in the five county red wolf recovery area from reported evidence of similar diets (Dellinger et al. 2011, McVey et al. 2013, Turner et al. 2011). Studies also show evidence of hybridization between the red wolf and coyote (Adams et al. 2003, Bohling et al. 2011, Hailer and Leonard 2008) but studies lack information on population es-

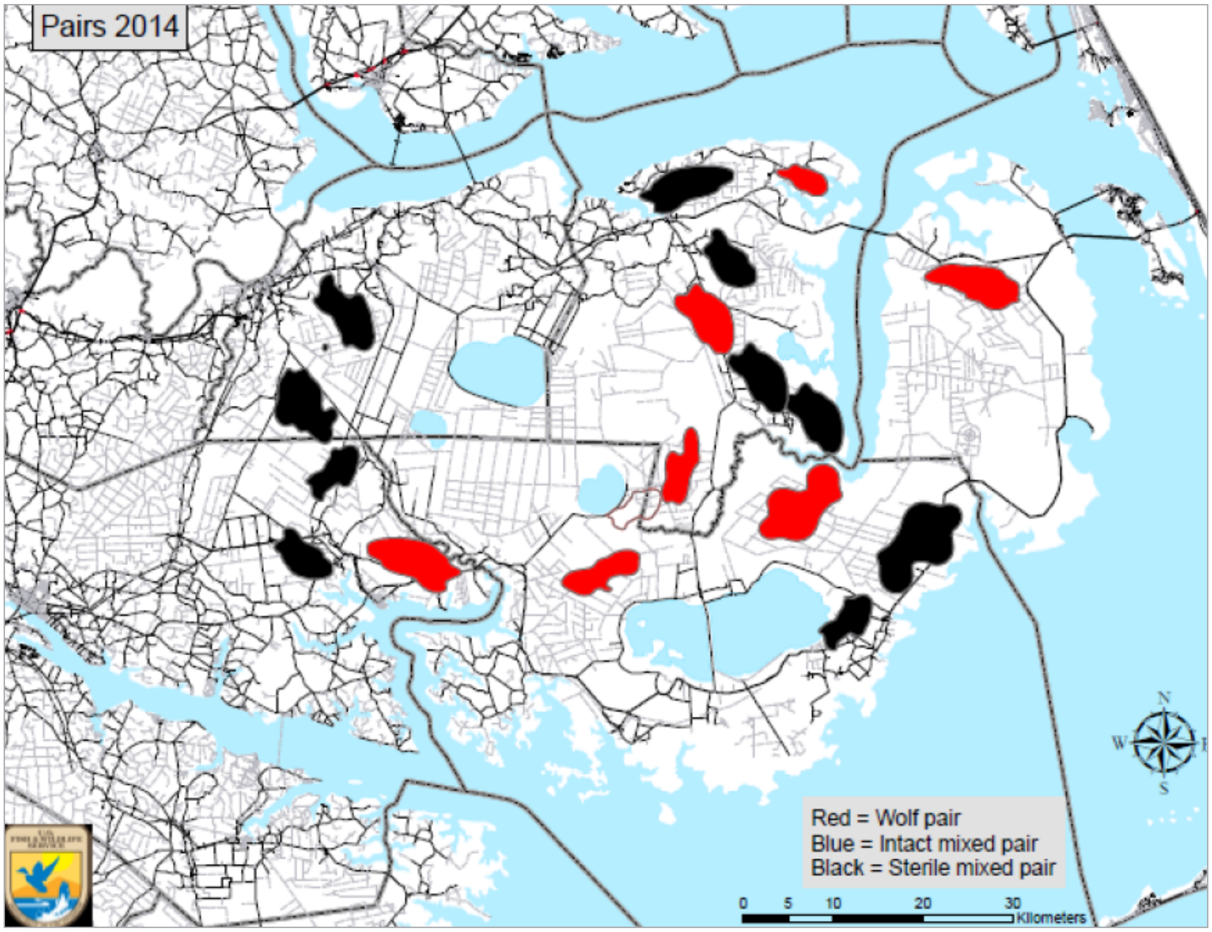

Figure 1. The general distribution and potential ranges of monitored red wolf and sterile wolf/coyote mixed pairs based on GPS movement data (Credit USFWS 2014).

timates and densities of these two species. Hybridization between these two species make it difficult to morphologically distinguish between species so throughout this study, we referred to Canis sp. (coyote, red wolf, wolf-coyote hybrid) as a large canid.

Due to minimal research on red wolf and coyote populations in eastern North Carolina, we conducted a pilot study to estimate occupancy rates to determine if using camera traps would be an effective method for evaluating populations of large canids. We compared detection and occupancy estimates of large canids on two different landscapes and the occurrence of radio-collared and non-collared individuals in the study area. We speculated that occupancy would be higher in agricultural landscapes due to high prey abundance. Comparing radio-collared and non-collared is important because it allows us to get a better understanding of how large canids are occupying public and private land and which of those are being monitored (radio-collared) by the USFWS. Local, private landowners have been considered to have a general distrust of the USFWS due to the lack of public awareness and for not upholding Red Wolf Recovery Plan objectives (Wildlife Management Institute 2014). Due to the sociological issues the public have about these animals being on the landscape, in would interest the public to know how many of these animals are on their land and what areas they occupy.

Study Area

We conducted our study in Hyde County, North Carolina. Hyde County is one of the five counties in northeastern North Carolina that is home to the USFWS Red Wolf Recovery Plan. Figure 2 shows a map of the Red Wolf Recovery Area (Southern Environmental Law Center 2012). By gaining private landowner permission, camera traps were placed on Lux Farms (3,179.ha), and public game land on the Long Shoal Tract (2,135.ha). Lux Farms includes Wetland Reserve Program (WRP) land, mixed pine-hardwood, brush land, pocosin type habitat, and agricultural fields. Agricultural fields are predominantly planted with corn, soybean, and wheat. The farm is broken up into 16 rectangular crop and agricul-

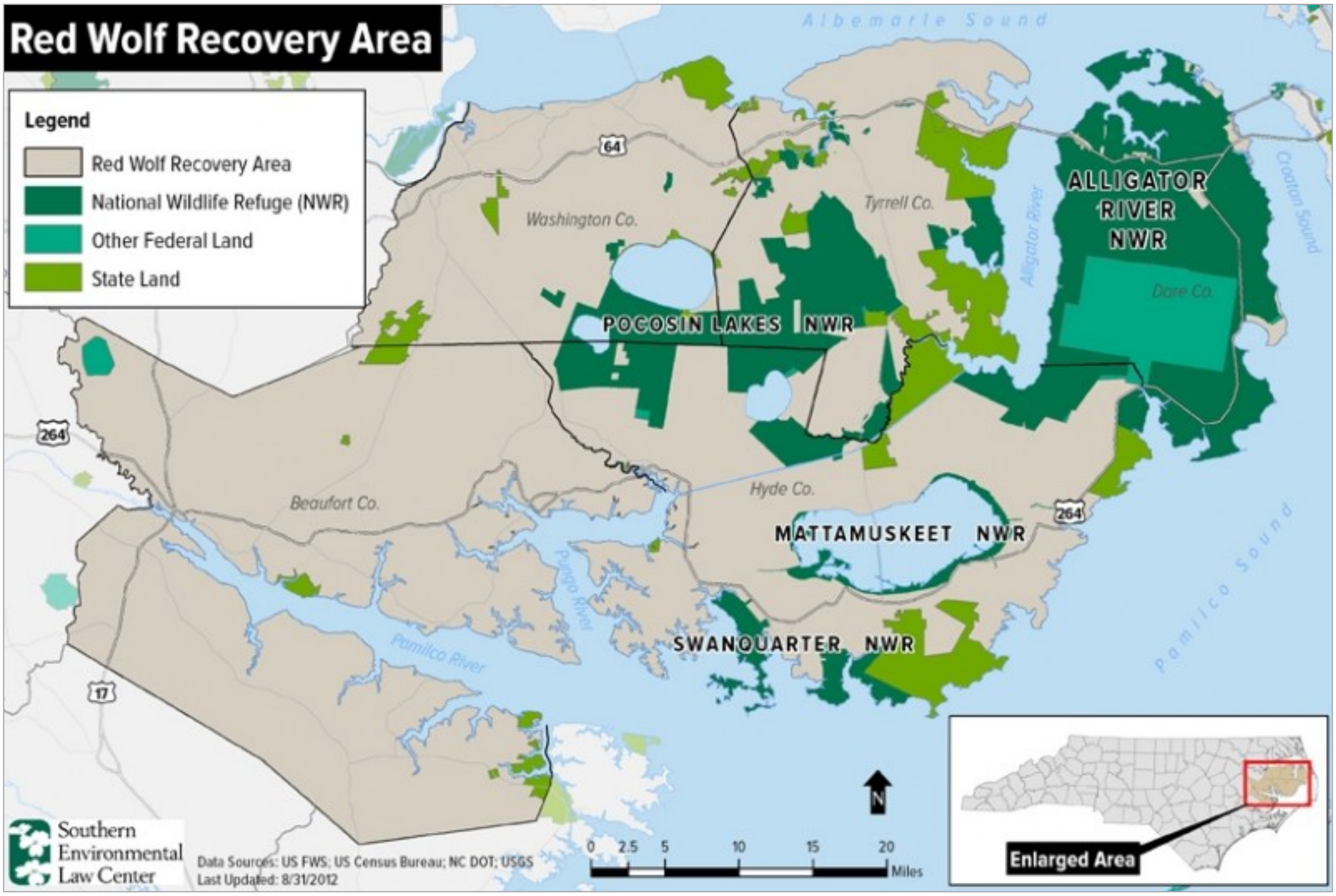

Figure 2. Map showing the Red Wolf Recovery Area and our survey area that is positioned just south of the Alligator River National Wildlife Refuge (Credit Southern Environmental Law Center 2012).

tural sections with unpaved roads running throughout the farm. The Game Lands we used consisted of hardwood swamp and pond pine pocosin habitat-types. Game lands are managed by the North Carolina Wildlife Resource Commission. Long Shoal consisted of several unpaved roads that we used to access the area while setting up the camera traps.

Methods

It has been documented that remote cameras can be useful for estimating site occupancy of large canids (O'Connell et al. 2006). However, detection probability for some elusive species, such as coyotes, can be low (Gompper et al. 2006). Occupancy models use species detection/non-detection data from repeated visits to estimate the probability of species occupancy while accounting for imperfect species detection and its relationship with survey covariates (Mackenzie et al. 2002. 2006). Not detecting a large canid during a sampling period could occur if either the species did not occupy the area or that the species occupied the area but was not detected at that particular site (MacKenzie et al. 2002).

Site Occupancy Model

The site occupancy model consists of two processes, one determining the true state system (occupied/not occupied) and the other the observation of the system state (detected/not-detected). The occurrence state at each site, Z_i, is binomial such that $Z_i \sim$ *Binomial* (Ψ_i, 1), where Ψ_i is the probability of occurrence and Z_i denotes the state of occurrence such that $Z_i = 1$ indicates site i is occupied and $Z_i = 0$ denotes the site as unoccupied (Kéry et al. 2010). In most cases, individuals are usually undetected at a site even when it is present, therefore making the probability of detection <1. Due to the conditions of the state process, the actual observational or sampling model at site i follows another binomial model. The product of Z_i and detection probability P_{ij} frames the success probability. The detection/ non-detection data Y_{ij} observed at site *i* during survey *j* is denoted as $Y_{ij} \sim Binomial\ (Z_i P_{ij}, 1)$, where Y_{ij} is the observation at site *i* during survey *j* and P_{ij} is the probability of detection. Replicate surveys provide the information about detection probability to allow the estimate of true occurrence Ψ (Kéry et al. 2010).

Site occupancy is simply the probability that a target individual is detected at a particular site. It is important to note that the size and placement of our study area is important when determining the definition of occupancy. Our study sites are within 1–2 orders of magnitude of estimated resident coyote territory size and to some extent surrounded by continuous habitat. During the period of sampling, it is likely than an individual large canid could move through both study areas and to multiple camera sites. The estimate of occupancy can been defined as frequency of use at that particular site because these animals have large home ranges and move frequently (Efford and Dawson 2012).

Data Collection

We used Reconyx PC900 HyperFire Professional High Output camera traps. We placed 17 cameras in our study area; 10 on Lux Farms and 7 on the Long Shoal Tract. The cameras were placed on trees and secured with Masterlock python cables. We focused mainly on placing cameras on unpaved roads because canids are known to use human manipulated areas for traveling (Way et al. 2004). On Lux Farms, cameras were placed along agricultural habitat and within forested habitat inside the Long Shoal Tract. Camera traps were active continuously for a total of 28 consecutive days from 26 June to 24 July 2014. A sampling occasion was defined as a 24-hr period. We recorded a detection as an event when at least one canid was detected at a camera during a sampling occasion. Due to hybridization and similar morphological features of a red wolf, coyote, wolf-coyote hybrid (Bohling and Waits 2008), we did not distinguish between species but collectively referred to these species as large canids.

Data Analysis

We estimated site occupancy of radio-collared canids and non-collared canids on the total land of Lux Farms and the Long Shoal Tract using package 'unmarked' in R (R Core Team 2012). We also estimated occupancy of canids separately on Lux Farms and the Long Shoal Tract. We ran two covariate models in our data analysis; including days surveyed as a covariate of detection and habitat type (forested or agricultural land) as a covariate of occupancy. We ran a covariate for days surveyed because a few of our cameras were moved out of the range of view by black bears (*Ursus americanus*), which produced varied survey days for some cameras. We did not include the habitat variable for the individual Lux and Long shoal models because they only had one habitat type. We used AIC to determine model fit. AIC model selection is used to show the relative quality of statistical models and deals with the trade-off of goodness of fit and model complexity. Due to AIC favoring lower residual error, the model with the lowest AIC value is the best fit. Assumptions of this project include 1) closed occupancy, so sites will be either occupied or not, 2) occupancy probability is constant, 3) detection probability can be modeled with covariates or survey period, and 4) detection of a species at a site independent of detecting the species at other sites, unless specifically modeled for (Conroy and Carroll 2009)

Results

Frequency of detections were generally low across sites and groups (Table 1). Radio-collared large canids had the lowest occupancy of 0.412 with the lowest estimated detection of 0.022 (Table 2). Non-collared large canid occupancy was estimated at 0.863 and with a detection rate of 0.031. The estimated combined occupancy of large canids on Lux Farms and the Long Shoal Tract was 0.737 with a detection estimate of 0.051. Canid occupancy on the Long Shoal Tract was highest at 0.999 with low estimated detection of 0.026. Occupancy of canids on Lux Farms was 0.630 with the highest detection estimate of 0.073. Based on AIC, the most supported model in our set was the null model (Table 3), indicating that that covariates had little to no effect on occupancy or detection.

Table 1. Frequencies of detections of radio-collared and non-collared large canids at individual camera locations (sites detected) on Lux Farms and Long Shoal Tract.

Location (# of cameras)	Sites detected
Lux Farms (10)	5 (50%)
Radio-collared	3 (30%)
Non-collared	4 (40%)
Long Shoal Tract (7)	4 (57%)
Radio-collared	0 (0%)
Non-collared	4 (57%)
Combined areas (17)	9 (53%)
Radio-collared	3 (18%)
Non-collared	8 (47%)

Table 2. Top model coefficients (standard error) and occupancy and detection rates for radio-collared and non-collared large canids on Long Shoal Tract and Lux Farms.

Model (FM1)	Occupancy estimate	Standard error	Detection estimate	Standard error
Radio-collared	0.412	0.361	0.022	0.020
Non-collared	0.863	0.337	0.031	0.014
Combined areas	0.737	0.016	0.051	0.198
Long Shoal Tract	0.999	0.029	0.026	0.011
Lux Farms	0.630	0.209	0.073	0.024

Table 3. Models and and associated number of parameters (K), Akaike's Information Criteria (AIC), delta AIC (ΔAIC), and model weights (Wt.) of occupancy rates of large canids on Long Shoal Tract, Lux Farms, and the two combined areas. Table also includes occupancy rates of radio-collared and non-collared large canids on the two combined areas relative to the null model (Fm1), days surveyed (Fm2), and habitat type (Fm3).

Model	K	AIC	ΔAIC	Wt.
Radio-collared				
Fm1	2	48.91	0	0.56
Fm2	3	50.71	1.80	0.23
Fm3	3	50.91	2.00	0.21
Non-collared				
Fm1	2	114.2	0	0.53
Fm2	3	115.56	1.36	0.27
Fm3	3	116.11	1.91	0.20
Combined areas				
Fm1	2	146.96	0	0.51
Fm2	3	148.10	1.14	0.29
Fm3	3	148.84	1.88	0.20
Long Shoal Tract				
Fm1	2	50.51	0	0.73
Fm2	3	52.50	1.99	0.27
Lux Farms				
Fm1	2	97.64	0	0.72
Fm2	3	99.52	1.87	0.28

Discussion

The occupancy for non-collared large canids was twice as high as radio-collared canids, but their estimated detection was fairly similar. Knowing that there are radio-collared individuals on the landscape gives us the indication that these animals could have migrated over from the ARNWR and that those canids are being monitored or have been in the past (USFWS 2006). Long Shoal had a somewhat higher large canid occurrence than Lux Farms which contradicted our hypothesis of having a higher occurrence near agricultural fields due the possibility of having a high prey base (Way et al. 2004, Hinton and Chamberlain 2010). These two landscapes are close to each other so it may be a matter of the large canids traveling through areas where our cameras were not located or that frequency of use is higher in the Long Shoal Tract. Results of high occupancy and low detection from an elusive species, such as coyotes, is not uncommon (Shannon et al. 2014). These results suggest that large canids are in the study area but are not being detected due to poor camera placement or not having a big enough sample coverage. Shannon et al. (2014) suggests that increasing the sampling approach in survey days (80–120 sampling occasions) and sample sites (≤30 cameras) will result in more precise estimates of occupancy.

Even though we did not directly model for detection of black bears in this study, it is important to note that bears were detected at every camera site. This is important because competition could be occurring between large canids and bears. Bears and large canids have somewhat similar diets (Hellgren et al. 1989, Landers et al. 1979, McVey et al. 2013) so competition could be occurring for food or habitat resources. Future research would be needed to document if this type of species competition is occurring.

The importance of the results from our occupancy and detection data show that large canids are on the landscape and are known to occupy areas on private land. The red wolf recovery program is a controversial issue including many stakeholders that are trying to determine if this program has worth and should be continued. This information provides a starting point to address issues and discuss management and conservation of large canids in eastern North Carolina. Recommendations for continued research include increased distribution, density, and duration of observation collections. Future research should include discussion of home-range size of target species and plot size to determine the design of occupancy studies in continuous habitat (Efford and Dawson 2012). Occupancy studies paired with occupancy-abundance relationships can be useful in monitoring wolf abundance if biological knowledge of the species and a sample unit size that complements wolf territory was incorporated into the survey design (Latham et al. 2014). Further research could provide more information on large canid densities and potential implications of having these species on the landscape.

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