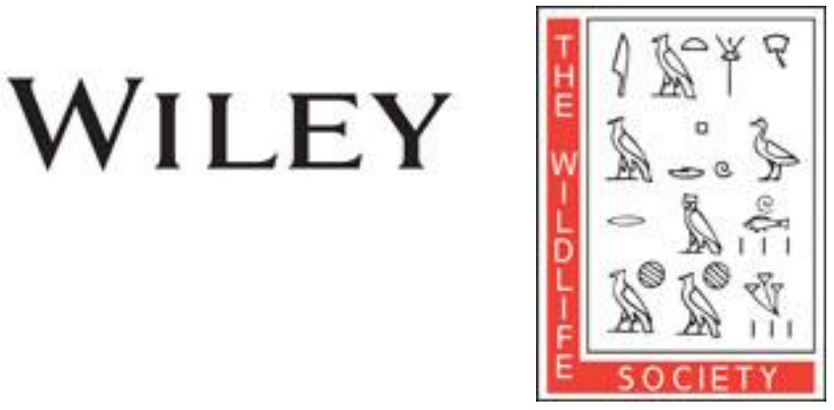

Journal of Wildlife Management 74(1):55–58; 2010; DOI: 10.2193/2008-583

Management and Conservation Note

Space and Habitat Use by a Red Wolf Pack and Their Pups During Pup-Rearing

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ABSTRACT During summer 2005, we evaluated space and habitat use by red wolves (*Canis rufus*) during pup-rearing. Home-range sizes for red wolves (3 ad, 3 juv, and 4 pups) varied from 3.48 km^2 to 12.24 km^2. Red wolves selected agricultural fields over adjacent forested areas and used less space during pup-rearing than we expected based on prior knowledge of the species. Attending pack members rarely left pups alone, pack members shared pup-rearing duties, and male red wolves appeared to play a significant role in pup-rearing.

KEY WORDS abdominal transmitter, *Canis rufus*, North Carolina, pup rearing, radiotelemetry, red wolf.

The release of captive-born red wolves (*Canis rufus*) into Alligator River National Wildlife Refuge during fall 1987 marked the first successful reintroduction of wolves in the contiguous United States. More importantly, it represented the first successful attempt to reintroduce a large predator that was completely extirpated from the wild. The red wolf remains critically endangered and has a wild population that fluctuates between 100 and 130 individuals (Fazio 2007).

Issues surrounding the natural history and decline of the red wolf have been documented (McCarley 1962, Nowak 2002, Phillips et al. 2003), and research during the postreintroduction phase of the recovery efforts has been dominated by studies addressing the status of the red wolf as a species (Wayne and Jenks 1991, Wilson et al. 2000, Kyle et al. 2006, Murray and Waits 2007). However, information on basic ecology of red wolves is lacking, which is fundamental to ensuring recovery and persistence of the species.

During summer 2005, the Red Wolf Recovery Program (hereafter Recovery Program) initiated a study to examine the potential for using intra-peritoneal radiotransmitters surgically implanted in red wolf pups <8 weeks old. This study represented an initial step to better understand red wolf ecology. As part of this study, the Recovery Program (primarily through the lead author of this paper) conducted daily monitoring of red wolf pups and their associated pack to determine ecological factors that may influence rates of pup mortality and to examine the spatial ecology of a red wolf pack during pup-rearing. To our knowledge, our study is the first to assess pup attendance in wild wolves by evaluating distances of pack members from radiotransmittered pups >18 weeks old. Previous studies that examined home-site attendance patterns of coyotes (*Canis latrans*) and gray wolves (*Canis lupus*) used distances to dens and activities around home sites as indicators of attendance (Andelt et al. 1979, Harrington and Mech 1982, Harrison and Gilbert 1985, Potvin et al. 2004). A common theme among some of these studies was that the relevant distance varied depending on how habitat structure limited visual observations of attending pack members. Our primary objectives were to describe home range and habitat use patterns of red wolves and their pups during pup-rearing, and to assess pup attendance behaviors in the last remaining population of red wolves. Our overarching hypothesis considered the effect of pup-rearing on red wolf space use and habitat use and included a nonbreeding pair of red wolves for comparison. We expected the breeding pack to have larger spatial needs (i.e., larger home range) than the nonbreeding pair, and that all older pack members (ad and juv) would participate in pup attendance.

STUDY AREA

The only viable population of wild red wolves occurs in northeastern North Carolina, USA (Fazio 2007). Five counties (Beaufort, Dare, Hyde, Tyrrell, and Washington) compose the Red Wolf Recovery Experimental Population Area (RWREPA), which is divided into 3 management zones and consists of approximately 607,041 ha of federal, state, and private land. To our knowledge, 115 individual red wolves and 15 breeding packs inhabited the RWREPA. Prominent red wolf habitat within the RWREPA included agricultural fields planted to wheat, corn, soybean, and cotton that were surrounded by pine (*Pinus* spp.) plantations, high pocosin (*Pinus serotina*, *Persea palustris*, *Acer rubrum*, *Nyssa tupelo*, and *Liquidambar styraciflua*) forests, pine–hardwood forest, gum (*Nyssa* spp.) swamp, and saltwater marsh. Primary prey of red wolves in the RWREPA were white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), rabbit (*Sylvilagus floridanus*), nutria (*Myocastor coypus*), and small rodents (Phillips et al. 2003). Other medium- to large-sized predators that coexisted with red wolves were gray foxes (*Urocyon cinereoargenteus*), red foxes (*Vulpes vulpes*), bobcats (*Lynx rufus*), coyotes, American alligators (*Alligator mississippiensis*), and black bears (*Ursus americanus*). Our primary study areas were in Beaufort County southwest of Pocosin Lakes National Wildlife Refuge. This area was the southwestern-most range of the RWREPA in which existing red wolves maintained territories on the outskirts of the RWREPA.

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METHODS

The Recovery Program traps red wolves annually with the goal of monitoring all red wolves within the designated RWREPA (Fazio 2007). Red wolves were captured by Recovery Program biologists using padded No. 3 foot-hold traps, and adult and juvenile wolves were fitted with mortality-sensitive radiocollars (Telonics, Inc., Mesa, AZ). The Recovery Program categorized red wolves >2 years old as adults, <2 years old as juveniles, and <1 year old as pups. Red wolves <9 months old were not radiocollared because they typically have not reached the minimum physical size to safely wear radiocollars. However, during spring 2005 we surgically implanted abdominal transmitters in pups as young as 8 weeks old from one pack to monitor pup survival and movements.

Red wolf pups were captured by Recovery Program biologists via foot pursuit and were restrained using nets. We implanted abdominal transmitters at the capture site. Initial anesthetic induction was achieved by placement in a chamber with 5% isoflurane (O_2 flow rate 3 L/min). General anesthesia was maintained during surgery using a Norman elbow rebreather and small mask with 2–2.5% isoflurane (O_2 flow rate 1 L/min). We monitored pups using a pulse oximeter, rectal thermometer, and a stethoscope. Before surgery each pup received butorphanol subcutaneously (0.3 mg/kg) and cephazolin (20 mg/kg) intramuscularly for pain control and antibiotics, respectively. Following presurgical preparation, a ventral midline skin incision approximately 3 cm was made approximately 1 cm caudal to umbilicus using a number 15 blade. The incision was carried through the linea alba to enter the abdominal cavity. Each gas-sterilized transmitter was tested with a radio receiver for signal and then rinsed with sterile saline. The transmitter (Advanced Telemetry Systems, Isanti, MN) was inserted through the abdominal incision parallel to the body wall. Transmitters were allowed to float freely within the abdominal cavity. Average time of the procedure (anesthesia induction to incision closure) was 25 minutes. Anesthesia was turned off and pups were provided with oxygen until purposeful movement returned. We cleared pups for release at the capture site once they were able to achieve sternal recumbancy and could hold their heads up, which took approximately 5–10 minutes. Pups were separated from parents for about 4–5 hours. During winter trapping in 2005 and 2006, Recovery Program biologists palpated the abdomens of the transmittered pups and successfully removed the transmitters.

Approximately 75% of the 115 known red wolves and 15 breeding packs with the RWREPA resided on private lands and access to private land was a crucial aspect of red wolf management. We selected one pack (Beechridge pack) and a pair of nonbreeders (Ransomville pair) for our work because these animals were near each other and resided on private lands where Recovery Program biologists had access. We monitored a nearby nonbreeding pair, the Ransomville pair, to compare space and habitat use between a pack of breeding red wolves and a pair of nonbreeding red wolves.

We systematically monitored wolves using a receiver and a 6-element Yagi antenna (Telonics, Inc.) mounted on a vehicle (Gilsdorf et al. 2008). We located all radiocollared wolves 1–5 times daily during 12-hour shifts. We separated sequential locations by at least 2 hours, and we monitored wolves during diurnal hours (0600–1759) for one week and during nocturnal hours (1800–0559) the following week. We maintained this monitoring schedule throughout the pup-rearing season from July to September. We estimated red wolf locations via triangulation using at least 3 bearings with an intersecting angle between 20° and 160°, which we recorded within 15 minutes. We subsequently used LOCATE III (LOCATE, Tatamagouche, NS, Canada) to estimate individual red wolf locations.

We estimated home ranges and core areas of red wolves during pup-rearing using a 95% and 50% fixed-kernel estimator, respectively, with least-squares cross-validation in the Animal Movement extension for ArcView 3.2. To determine habitat availability for individual red wolves, we used an a priori method in which we pooled all locations of wolves associated with their packs and we constructed a 100% minimum convex polygon (MCP) for each pack. We overlaid MCPs for each pack onto 1998 color-infrared digital orthophotos of the 5 counties in the RWREPA (obtained from North Carolina Department of Transportation [2005]) and determined the proportion of each MCP comprised of each habitat type. We assumed that these habitats were available to all pack members and defined habitat as the predominant vegetation or land-use type.

We classified habitats as forest, corn, soybean, cotton, and other (e.g., hog farms, pasture, residential homes, etc.) via ground truthing. We subsequently compared location data collected on radiocollared individuals and the percentage of habitats available to that individual's pack. We used Bonferroni confidence intervals to quantify preference, avoidance, and random use of habitat types (White and Garrott 1990).

We observed the frequency distribution of distances from adults and juveniles to pups in 100-m increments, and we adopted a similar approach used by Harrison and Gilbert (1985) and Andelt et al. (1979) because use of corn and cotton fields for cover prohibited observation of red wolf activity at rendezvous sites. We assumed a conservative approach by assuming attendance occurred only at distances <250 m. Therefore, we assumed that attendance occurred if adult or juvenile wolves were within 250 m of a radiomarked pup.

RESULTS

We obtained 1,026 locations on 10 red wolves (3 ad, 3 juv, and 4 pups) from mid-July to mid-September 2005. Of the 1,088 attempts we made to locate all 10 wolves, 94% of attempts were successful. Home-range sizes varied from 3.48 km^2 to 12.24 km^2. Mean home-range size during pup-rearing was 5.71 km^2 and a mean core-area size was 0.91 km^2. The adult and juvenile members of the Beechridge pack had a mean home-range size of 5.74 km^2 and the nonbreeding Ransomville pair had a mean home-range size of 9.55 km^2. Beechridge pups had a mean home-range size

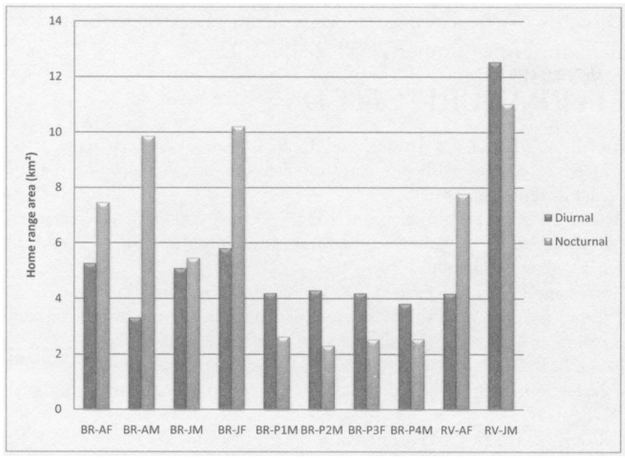

Figure 1. Home-range area (95% fixed kernel) for 10 red wolves in the Beechridge (BR) pack and Ransomville (RV) pair of red wolves during diurnal and nocturnal periods in northeastern North Carolina, USA, during pup-rearing, 2005 (Jul–Sep). Codes on the *x*-axis indicate pack, age class (ad [A], juv [J], and pups [P]), and sex of individuals.

of 3.76 km^2. Adult and juvenile red wolves increased their space use during nocturnal hours (from 6.03 km^2 to 8.63 km^2), whereas red wolf pups decreased their space use during nocturnal hours (from 4.12 km^2 to 2.50 km^2; Fig. 1). The Ransomville pair had an 11% increase in space use during nocturnal hours (from 8.36 km^2 to 9.40 km^2), whereas the adult and juveniles of the Beechridge pack had a 41% increase in space use during nocturnal hours (from 4.86 km^2 to 8.24 km^2). Beechridge pups had a 39% decrease in space use during nocturnal hours (from 4.12 km^2 to 2.50 km^2).

Habitat availability was similar for the Beechridge and Ransomville packs. Mean percentage of time red wolves spent in agricultural fields during pup-rearing was 98.38%; both packs showed a preference for corn and cotton fields and avoided wooded areas (Table 1). During nocturnal hours, red wolves decreased their use of cornfields (from 69.6% to 45.5%), and increased their use of cotton (from 26.1% to 34.8%) and soybean (from 3.3% to 17.5%) fields.

The female breeder of the Beechridge pack denned and whelped in a forest stand on the eastern range of the pack's territory. At about 4–6 weeks old, Beechridge pups were moved by the pack approximately 2,000 m west into cornfields where 4 of those pups were later captured by Recovery Program biologists. Recovery Program biologists recaptured 8 of the 9 Beechridge pups during the 2005 and 2006 winter trapping season; hence, we assumed that only one pup of the litter died during pup-rearing. When recaptured, transmittered pups weighed an average of 26 kg (SD = 3.92 kg), whereas non-transmittered pups weighed an average of 21 kg (SD = 5.26 kg). During pup-rearing, the Beechridge pack established 3 known rendezvous sites in corn (2 sites) and soybean (1 site) fields. Vegetation height prevented us from observing animals and their activities. We only saw the wolves when they used secondary dirt roads, and later in the season, we saw them in harvested crop fields. We found red wolf pups within 250 m of older pack members 77% of the time. We observed 63% of adult locations and 47% of juvenile locations within 250 m of a pup. We found both sexes simultaneously attending pups 39% of the time, but females attended pups more than males on a solitary basis (25% vs. 13%). We found red wolves attending pups more often during day than night (88% vs. 64%).

DISCUSSION

Our findings offer an initial glimpse into space use and pup-rearing behavior of free-ranging red wolves being restored to northeastern North Carolina. We found that a breeding red wolf pack had a smaller home range than a nonbreeding red wolf pair during pup-rearing. Our estimates of home range during pup-rearing were smaller than we anticipated given our understanding of red wolf ecology, as well as that of other large, social canids (Phillips et al. 2003). Likewise, red wolf pups restricted movements during nocturnal hours, whereas adults increased their movements. Finally, red wolves showed a strong preference for agricultural fields during pup-rearing.

In regard to adult and juvenile attendance patterns, our results were similar to those found in gray wolf studies (Harrington and Mech 1982, Potvin et al. 2004). During diurnal hours, adult red wolves restricted their space use and were rarely located away from pups. However, during nocturnal periods attendance of pups by adults and juveniles decreased, and adults expanded their space use while pups restricted their movements to home sites. To our knowledge, our results are the first to show inverse movement patterns for wolf pups and older pack members during diurnal and nocturnal hours. Adults increased movements at night to forage, and pups most likely consolidated their activities to home sites for security and to wait for feeding opportunities.

We rarely located red wolves in forested areas; practically all locations occurred within agricultural fields planted to corn, soybeans, and cotton. Wolves concentrated their activities in cornfields, particularly during diurnal periods,

Table 1. Bonferroni confidence intervals for the proportion of red wolf locations (n = 1,026) for a breeding pack and nonbreeding pair found in each of 5 habitat types in northeastern North Carolina, USA, during pup-rearing, 2005.

		Red wolf locations		
Habitat type	**Proportion of habitat**	**Proportion of locations**	**CI**	**Preference**
Corn	0.199	57.9	$0.549 \leq P_{corn} \leq 0.609$	Preferred
Cotton	0.199	30.3	$0.276 \leq P_{cotton} \leq 0.332$	Preferred
Soybean	0.299	10.2	$0.085 \leq P_{soybean} \leq 0.122$	Avoided
Woodlot	0.233	0.8	$0.004 \leq P_{woodlot} \leq 0.015$	Avoided
Other	0.070	0.8	$0.004 \leq P_{other} \leq 0.015$	Avoided

and moved out of cornfields during nocturnal periods presumably to forage for prey in surrounding agricultural fields. We suspect that the extensive use of agricultural fields was at least partially a function of abundant foraging opportunities often associated with agricultural habitats (Atwood et al. 2004, Brinkman et al. 2004). However, it was somewhat surprising to observe wolves spending practically all of their time during diurnal periods in agricultural habitats, as one would expect them to use forested habitats during summer (pup-rearing) when summer temperatures are extreme. A plausible explanation is that agricultural habitats offer quality foraging habitat. Also, concentrating daily activities in agricultural habitats may reduce harassment from biting insects, reduce external parasite loads (e.g., ticks), and potentially influence pup survival.

Management Implications

Effective management of the only red wolf population largely depends on understanding and predicting habitat needs. We suggest agricultural habitats within the RWREPA provide summer (pup-rearing) habitat for red wolves. Within the landscape of northeastern North Carolina, red wolves overwhelmingly selected farmed fields with row crops for protective cover and foraging habitats over surrounding forested areas. When interpreted in combination with our observations of space use, the use of agricultural fields offers compelling information likely to assist long-term management needs of red wolves, particularly because red wolves currently exist in an agriculture-dominant landscape. Our study offers a first indication of where important pup-rearing habitat may exist in northeastern North Carolina and an important aid in designing future studies to help understand critical habitat for red wolves within the northeastern North Carolina landscape.

Acknowledgments

We thank the Red Wolf Recovery Program for their continued support. We thank C. Lucash and F. Mauney for their assistance, encouragement, and helpful suggestions. We thank A. Acton for volunteering her service to implant abdominal transmitters in red wolf pups. Thanks to B. Fazio, A. Beyer, M. Morse, L. Schutte, K. Whidbee, and D. Hendry for their support and insights. Special thanks to E. Siemann and Rice University for support of this thesis project. Research was funded by the Red Wolf Recovery Program and the Wray-Todd Graduate Fellowship. We appreciate comments provided by L. Brennan and 2 anonymous reviewers that greatly improved the manuscript. This manuscript was approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript number 2008-241-2311.

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Acting Editor-in-Chief: Brennan.