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**Home range, habitat use and pup attendance of red wolves (*Canis rufus*) during the pup rearing season.**

by

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# ABSTRACT

Home Range, Habitat Use and Pup Attendance of red wolves
(*Canis rufus*) During the Pup Rearing Season

by

Joseph William Hinton

Despite a 20 year reintroduction effort into northeastern North Carolina, little is known about the natural history and ecology of red wolves (*Canis rufus*). In 2005, I studied home ranges, habitat use and pup attendance of red wolves during the pup rearing season. Data indicated that red wolves have home range sizes intermediate between those of coyotes (*Canis latrans*) and gray wolves (*Canis lupus*). Similar to other canids in the eastern United States, red wolves preferred to use extensive agricultural fields during the summer months rather than adjacent wooded areas. Red wolves abandoned dens early to move pups into adjacent agricultural fields. Consistent with pup rearing studies done on gray wolves, red wolf pups were rarely left alone indicating that red wolves share duties of pup rearing and that males play a significant role in the rearing of red wolf pups.

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# Chapter 1

## Introduction

Large carnivores have historically been subject to extermination efforts due to perceived threats to human enterprise. Within the United States, wolves have been extirpated from much of their historical ranges as government-supported eradication campaigns began to protect agricultural interests. One species of wolf that had been extirpated completely from it historical range and to the brink of extinction was the red wolf. The red wolf (*Canis rufus*) once ranged throughout the southeastern United States. Fossil and historical records indicate that red wolves inhabited an area from the Atlantic coast west to central Texas, with the Ohio River Valley and central Pennsylvania being its northernmost range and their distribution formerly extending south to the Gulf of Mexico (Nowak 2002). Sharing a similar fate as its relative the gray wolf (*Canis lupus*), the red wolf was extirpated from its historical range as a result of indiscriminate killing, predator control programs, and habitat destruction (Lucash et al. 1999). By the 1970s, it was believed that the entire remaining red wolf population was confined to a small coastal area of Texas and Louisiana and numbered less than 100 individuals. Hybridization between red wolves and the expanding coyote (*Canis latrans*) populations occurred when both gray wolves and red wolves were extirpated and habitat barriers were eliminated when landscapes were changed to suit human needs (Van Manen et al. 2000). To prevent the extinction of red wolves, U.S. Fish and Wildlife Services (FWS) captured as many wild red wolf-like canids as possible from 1974-1980. Of those captured, only 17 met the criteria established to define the species and were used to begin the captive breeding program. In 1986, FWS reintroduced the red wolf into northeastern North Carolina. Currently, this is the only free roaming, wild population of red wolves.

Despite the red wolf's high profile endangered species status, red wolf ecology and natural history are poorly understood. The most notable literature on the red wolf examines its recovery (Lucash et al. 1999; Van Manen 2000; Phillips et al. 2003) and status as a species (Wayne and Jenks 1991; Wayne and Gittleman 1995; Nowak 1992; Nowak 1998; Wilson et al. 2000). Lacking in the current literature are data on the natural history and ecology of this species. Although the genetic health of red wolves has received the most attention, many other aspects of wolf biology will affect the population growth and persistence of this species. The purpose of this research was to better understand red wolf natural history and ecology to support effective, long-term conservation and management of red wolves.

Current radio-tracking data available for red wolves estimate home range sizes vary from 18 $km^2$ to 200 $km^2$ (Riley and McBride 1972; Shaw 1975; Phillips et al. 2003; Mauney 2005). However, the accuracy of this data is questionable for a number of reasons. First, datasets from red wolf populations in Texas and Louisiana prior to the restoration efforts are based on relatively small samples from remnant red wolf populations in poor health (Phillips et al. 1995; Phillips et al. 2003). Secondly, Red Wolf Recovery Program biologists monitor red wolves to address specific management needs for the restoration project. As a result, monitoring is not conducted in a systematic way or applied evenly across the population. These issues make using previous datasets problematic.

The study described in Chapter 2 is one that systematically sampled red wolves during diurnal and nocturnal activities during a defined biological season with the purpose of gaining insights into red wolf home range and habitat use relevant to the pup rearing season. For this study, I monitored a breeding group (two adults, two juveniles, and four pups) and a non-breeding group of two (one adult and one juvenile) during the 2005 pup rearing season. Red wolves were found to have home ranges (59 $km^2$ to 110.6 $km^2$) during the pup rearing season intermediate of the previous home range estimates (18 $km^2$ to 200 $km^2$) for the species. Adult and juvenile nocturnal use of territories were much larger than their diurnal use, while red wolf pups consolidated to rendezvous sites at night and were more active during the day. Also, red wolves were found to prefer habitats dominated by agriculture over wooded areas during the summer and concentrated both diurnal and nocturnal activities in corn, cotton, and soybean fields.

Chapter 3 is a pilot study to examine the use of abdominal transmitters in red wolf pups to monitor their survival and to better understand red wolf behavior during the pup rearing season. Although none of the transmittered pups died during the study, valuable information was gathered on red wolf rendezvous site use, pup activity, and attendance by breeding and non-breeding wolves within the pack.

Results of my study indicate that the red wolf population is highly accessible to researchers because of the density of roads and agricultural fields. In concert with mild winters, this makes conducting studies on the current population to obtain data on red wolf natural history and ecology during the meaningful biological seasons very feasible.

Also, using abdominal transmitters in pups is a feasible method of monitoring red wolf pups and allows both biologists an opportunity to monitor the survivorship and behavior of all age classes within the red wolf population.

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# Chapter 2

## Red Wolf (*Canis rufus*) Home Range and Habitat Use during the Pup Rearing Season

### Abstract

The red wolf (*Canis rufus*) is an endangered canid endemic to the southeastern United States. Once the dominant canid in that region, the few remaining individuals were removed from eastern Texas and western Louisiana. Despite a 20 year reintroduction effort into northeastern North Carolina, little is known about the natural history and ecology of red wolves. In the summer of 2005, I studied the home ranges and habitat use of 10 radio-tagged red wolves belonging to a breeding pack and a non-breeding pair. To complement data collection on juvenile and adult red wolves, abdominal transmitters were surgically implanted in red wolf pups younger than 10 weeks of age to collect spatial data on all age classes. Between July to September 2005, 1088 locations were obtained. Home ranges averaged 74.1 $km^2$. Mean home range size of adult red wolves (76.1 $km^2$) were intermediate of juveniles (88.9 $km^2$) and pups (61.5 $km^2$). Both packs concentrated their activities during the pup rearing season in agricultural croplands and avoided wooded areas.

**Key Words:** Red wolf, *Canis rufus*, home range, habitat use, pup rearing.

**Introduction**

Prior to European settlement in the southeastern United States, the red wolf (*Canis rufus*) had been the dominant large canid species in that region (Nowak 2002). Despite their once widespread abundance in the southeast, red wolves were eradicated from their former range as a result of habitat destruction, indiscriminate killing, and government bounties (Lucash et al. 1999; Nowak 2002). Listed as an endangered taxon in 1967, it became one of the first animals to attract federal protection and recovery efforts with the passage of the Endangered Species Act (ESA) in 1973 (U.S. Fish and Wildlife Service 1989). Under the protection afforded by the ESA, a recovery team was created to guide red wolf recovery efforts. Legal protection, improved habitat, and relocation efforts by the Red Wolf Recovery Program enabled red wolves to reestablish in Alligator River National Wildlife Refuge (ARNWR), Pocosin Lakes National Wildlife Refuge (PLNWR) and surrounding private, state, and federal lands in northeastern North Carolina. Issues surrounding the natural history and decline of the red wolf have been documented by a number of researchers (McCarely 1962; Paradiso and Nowak 1972a; Nowak 1979; McCarley and Carely 1979; Phillips et al. 1995; Lucash et al. 1999; Van Manen 2000; Phillips et al. 2003).

Despite the intensive studies conducted to understand grey wolf (*Canis lupus*) and coyote (*Canis latrans*) natural history and ecology, the natural history and ecology of red wolves is not understood as well. The early eradication of red wolves prior to the turn of the $20^{th}$ century prevented the documentation of red wolf natural history (U.S. Fish and Wildlife Service 1989). Early research prior to the removal of the few remaining red wolves from the wild focused on identification techniques essential to the captive breeding phase of the species recovery plan (Lawrence and Bossert 1967; McCarely 1978; Paradiso and Nowak 1972; Nowak 1979). Research during the post-reintroduction phase of the recovery efforts has been dominated by studies addressing the status of the red wolf as a species (Wayne and Jenks 1991; Wayne and Gittleman 1995; Nowak 1992; Nowak 1998; Phillips and Henry 1992; Wilson et al. 2000). Regardless of the debate of the red wolf's origin, the fact remains that a large predator has been reintroduced into a small portion of the southeast. Given the severity of human impacts on the landscape in the southeast, it is hoped that a social predator with a large home range size and the ability to use many types of habitats will be able to maintain a stable and viable population. It is important at this time in the recovery of red wolves to conduct long-term research to evaluate its role as a functional component of the northeastern North Carolina landscape.

Home range and habitat use studies are important investigative tools for wildlife biologists to elucidate ecological requirements of animals (Schoener 1968; Harestad and Bunnell 1979; Johnson 1980; Rosenzweig 1981). Resources essential for an animal's survival are usually included in home ranges and the nonrandom use of habitat types within home ranges may indicate the importance of specific biological requirements for the resident. The size, shape, and structure of red wolf home ranges and the ways red wolves use habitats available to them may provide information to managers on how red wolf home ranges are located in the landscape, increase their understanding of time budgets, indicate resource requirements and social cohesion, and will help predict the likelihood of red wolf encounters with conspecifics, coyotes, or humans (Schoener 1968; Harestad and Bunnell 1979; Covich 1976; Van Manen 2000).

I describe here seasonal home range sizes and habitat use by red wolves during a portion (July – September) of the pup rearing season. There are a number of studies that have examined the home range sizes and habitat use of coyotes (Harrison and Gilbert 1985; Gese et al. 1988; Harrison et al. 1991; Person and Hirth 1991; Holzman et al. 1992; Gosselink et al. 2003) and grey wolves (Ciucci and Mech 1992; Jedrzejewski et al. 1993; Ciucci et al. 1997; Okarma et al. 1998; Norris et al. 2002; Theuerkauf et al. 2003; McLoughlin et al. 2004) either directly or indirectly. Despite several estimates of red wolf home range from management data, no study exists that explicitly examines red wolf home range and habitat use. This pilot study is the first time abdominal transmitters have been used in red wolf pups younger than 10 weeks of age. The study quantified home range size and habitat use of red wolf pups younger than 20 weeks of age. Study objectives were to describe and compare home range size and habitat use of adults, juveniles, and pups in a breeding pack (Beechridge) and a non-breeding pair (Ransomville) of red wolves during the pup rearing season.

**Study Area**

The only wild, free roaming population of red wolves occurs in five counties (Beaufort, Dare, Hyde, Tyrrell, and Washington) in northeastern North Carolina. These counties make up the Red Wolf Recovery Area, which is divided into three management zones and consists of approximately 607,041 hectares of federal, state, and private land. The primary study areas were in Beaufort County (approximately 35°N, 76°W). Data were collected from July – September 2005 from red wolves located on private agriculture fields just southwest of Pocosin Lakes National Wildlife Refuge (PLNWR). The climate of northeastern North Carolina is typical of the mid-Atlantic: four full seasons, nearly equal in length, with an annual precipitation averaging 122 to 132 centimeters. Beaufort County is hot and humid in the summer with temperatures ranging from 27°C to over 38°C. Winters are relatively cool with several incidents of snowfall. Typical temperature ranges in the winter are -4°C to 7°C.

Of the numerous habitats red wolves encounter throughout the Recovery Area, pine plantations, pocosin forest, mixed pine-oak forest, gum swamp, saltwater marsh, and agricultural fields are used. Red wolves monitored in this study used a number of these habitats such as agricultural fields, commercially managed loblolly pine (*Pinus taeda*) forests, and mixed pine/hardwood forests. Dominant agriculture fields that red wolves used during the study were corn (*Zea mays*), soybean (*Glycine max*), cotton (*Gossypium sturtianum*), and livestock pastures (cattle and hog ranches). Dominant trees in mixed pine-oak forests were pines (*Pinus* spp.), oaks (*Quercus* spp.), maples (*Acer* spp.) and hickories (*Carya* spp.). Understories of mixed pine-oak forests were made up of hawthorns (*Crataegus* spp.), bayberries (*Myrica* spp.), hollies (*Ilex* spp.), greenbrier (*Smilax* spp.), fox grape (*Vitas labrusca*), trumpet-creeper (*Campsis radicans*), and Virginia creeper (*Parthenocissus quinquefolia*).

**Methods**

Nearly all wild free roaming red wolf individuals in northeastern North Carolina are currently trapped and monitored, via radio-telemetry, by the Red Wolf Recovery Program (USFW 1989). To ensure that all red wolves are closely monitored for management purposes, the Recovery Program biologists conduct annual trapping for the placement and maintenance of radio-collars and monitor radio-collared red wolves twice a week by air. To capture adult and juvenile red wolves, Recovery Program biologists use steel, leg-hold traps with padded, offset jaws. Red wolves younger than nine months are not radio tagged because red wolves do not reach the minimum physical size to safely wear radio-collars until they are about nine months of age. However, in an effort to obtain data on pup survivability, the Recovery Program has recently focused efforts on using abdominal transmitters in pups as young as six weeks of age. Part of this study was to evaluate the effectiveness of abdominal transmitters for monitoring red wolf pups. Red wolf pups were captured with salmon nets by biologists. All captured red wolves are individually weighed, sexed, vaccinated, and inspected for general physical condition. For this study red wolves more than 9 months old were fitted with radio collars and radio transmitters were surgically placed in the abdominal cavities of red wolf pups less than 9 months old.

Radio-collared wolves were systematically located 1 to 5 times during daily 12 hour shifts using a receiver and a 6-element Yagi antenna (Telonics, Inc., Mesa, AZ.) mounted on a vehicle. Radio radio-collars were placed in nearby fire towers to use as beacons to orient the compass rose prior to field triangulating individual wolves. Sequential locations were separated by at least 2 hours. Diurnal and nocturnal monitoring alternated on a weekly basis. All individual red wolf locations were estimated from triangulation methods in the field that used at least 3 compass bearings with an intersecting angle between 20° and 160° recorded in less than 15 minutes. Telemetry error was determined by reference collars and transmitters in known locations to be ±2.5° for both. Mean error for reference collars and transmitters were 11.79m and 19.22m, respectively. Universal Transverse Mercator (UTM) coordinates and compass bearings from the field triangulations were imported into LOCATE III (LOCATE, Tatamagouche, NS, Canada) to estimate individual red wolf locations in 5-digit easting and 6-digit northing UTM coordinates. ArcCatalog (ESRI, Redlands, California) was used to generate point shapefiles for the wolf datasets. Individual red wolf location point shapefiles were imported into ArcView 3.2 (ESRI, Redlands, California) and ArcView 9.1 (ESRI, Redlands, California) to analyze spatial data.

Home ranges were estimated and quantified using the Animal Movement 2.2 extension for ArcView 3.2. Individual red wolf home range sizes were estimated using fixed-kernel estimator method with least squares cross validation (LSCV) using 95% of the point locations to exclude the effects of random sallies (Worton 1989; Seaman and Powell 1996; Gitzen and Millspaugh 2003). Using the geographic coordinates of radio-tracking locations, the fixed-kernel method creates areas of varying utilization distribution (UD). Areas that are more frequently utilized than others within the home range are shown by the kernel methods.

Habitat use-availability analysis was done to examine red wolf habitat selection during the pup rearing season. The method used was the comparison of location data collected on radio-collared animals and the percentage of habitat available to the animal's family unit. A GIS polygon of the study area's habitat types was overlaid onto the orthophotos obtained from the North Carolina Department of Transportation website (http://www.ncdot.org/it/gis/DataDistribution/default.html) to analyze habitat selection. Each habitat type was then measured using tabulate features built into ArcView 9.1. Habitat availability for individual red wolves was determined by pooling all locations of wolves associated with their packs and construction of a 100% Minimum Convex Polygon. Habitat measurements were quantified and these habitats were assumed to be "available" to all members of that pack. The five habitats defined in this study were woodlots, corn, soybean, cotton, and other (hog farms, cattle fields, residential homes, etc.). Habitat types and availability within the pack's 100% Minimum Convex Polygon (MCP) was measured and quantified. Chi-square ($\chi^2$) tests and confidence intervals were used to test for wolf preference, avoidance, or random use of habitat types (White and Garrott 1990).

**Results**

From mid-July to mid-September during the 2005 pup rearing season 1042 estimated locations for 10 wolves were obtained. Throughout the study season, 95.77 % of the 1088 total attempts that were made to locate all 10 wolves were successful. Of these estimated locations, only 3% of them were visual confirmations. The percentage of failed attempts to locate individual wolves did not differ between radio-collars and abdominal transmitters ($F_{1, 1024} = 0.07$, $P = 0.7943$). However, there was a significant difference in the size of error polygons ($F_{1, 1024} = 20.26$, $P = 0.002$). Mean error polygons for radio-collars were larger ($2.191 \pm 0.305$ km$^2$) than those for abdominal transmitters ($1.482 \pm 0.058$ km$^2$). Although error polygons for radio-collars were not influenced by habitat type ($F_{4, 598} = 1.69$, $P = 0.1672$), habitat type did influence the size of error polygons for abdominal transmitters ($F_{2, 424} = 22.85$, $P < 0.0001$).

*Home Range*

Home ranges determined for red wolves using 95% kernel density estimators varied in size (Table 1). Total home range varied from 59.0 km$^2$ to 110.6 km$^2$. Mean home range size was 74.1 km$^2$ and mean core home range size was 29.74 km$^2$. No significant difference was found in mean home-range size between male and female wolves ($F_{1, 8} = 0.17$, $P = 0.6850$) or between mean day and night home ranges ($F_{1, 18} = 0.24$, $P = 0.6275$). Although, age differences in home range were not quite significant ($F_{2, 6} = 4.66$, $P = 0.0517$) there was a significant difference between pup and juvenile wolf home range size using a Tukey test ($q = 2.95$, $\alpha = 0.05$) with juvenile home range sizes being much larger. Numerically, mean adult home range size (76.1 $km^2$) was intermediate to those of juveniles (88.9 $km^2$) and pups (61.5 $km^2$). Significant differences in home range size were found for social status of red wolves ($F_{2, 6} = 5.08$, $P = 0.043$) and size differed between packs ($F_{1, 8} = 10.20$, $P = 0.013$). There was a significant interaction of time of day and age ($F_{2, 6} = 5.52$, $P = 0.0171$), in which pups reduced home range size at night ($F_{1, 2} = 64.15$, $P < 0.0001$), adults increased home range size at night ($F_{1, 1} = 10.30$, $P = 0.0115$), and no difference was found for juveniles ($F_{1, 1} = 0.09$, $P = 0.9154$). No significant differences were found for size of core area and sex ($F_{1, 8} = 0.03$, $P = 0.874$), age ($F_{2, 6} = 0.22$, $P = 0.805$), social status ($F_{2, 6} = 1.18$, $P = 0.360$), and pack ($F_{1, 8} = 0.03$, $P = 0.876$).

*Habitat Use*

To examine the habitat-use patterns of red wolves during the pup rearing season, I classified five habitat categories (corn, cotton, soybean, woodlot, and other) used in the analysis of habitat use. Habitat type and availability for Beechridge and Ransomville were similar (Figure 1). The mean percent of time red wolves spent in agricultural fields during the pup rearing season was 98.38% (Figure 2). Both red wolf packs showed a strong preference for corn fields and avoided wooded areas during the pup rearing season (Table 2 and Table 3). The non-breeding Ransomville pair used cotton and soybean fields in proportion to their availability (Table 2). Individuals in the Beechridge pack showed a general avoidance of soybean, but preference, avoidance, and random use of cotton varied among members of the pack (Table 2).

Overall habitat use differed between day and night ($\chi^2 = 18.0$, df = 1, P = 0.0012). At night red wolves decreased their use of corn fields from 69.6% to 45.5%, and increased their use of cotton (26.1% to 34.8%) and soybean (3.3% to 17.5%) fields. Although no significant difference was found in habitat use and month ($\chi^2 = 10.4$, df = 4, P = 0.4426), there was slight decrease in the percentage of use of cotton fields and an increase in the use of soybean fields as the season progressed. Habitat use was independent of red wolf sex ($\chi^2 = 3.8$, df = 4, P = 0.4371), age ($\chi^2 = 9.3$, df = 2, P = 0.3205), and social status ($\chi^2 = 7.9$, df = 2, P = 0.4426).

**Discussion**

Home range and habitat use of red wolves are critical components of understanding how red wolf packs distribute themselves over the landscape. Such information will be needed for appropriate strategies to mitigate the effects of the changing landscape in northeastern North Carolina on red wolf populations. Although the home range and habitat use datasets presented here are small and the conclusions are tentative, they represent baseline data on red wolves from which additional hypotheses can be developed and tested. Additionally, the data presented here are the only information to date on the home ranges and habitat use of red wolves during the pup rearing season, and are the only spatial data on red wolf pups.

Home-range sizes of red wolves were intermediate in comparison to existing red wolf home range estimates. Previous home-range estimates from Texas, Tennessee, and North Carolina were reported to vary from 18 $km^2$ to 200 $km^2$ (Riley and McBride 1972;

Shaw 1975; Phillips et al. 2003; Mauney 2005). Contrary to intuition, the non-breeding Ransomville pair had a larger home range size than did the Beechridge pack (Figure 3). Although such differences could be attributed differences in prey density/availability or because the need to feed pups and maintain pack cohesiveness would cause breeding packs to have larger home-range sizes than do non-breeding pairs, such measurements were not part of this study. Albeit, the results here support other studies that have shown that pack size has little effect on home range size (Potvin 1988; Fuller 1989). Beechridge breeders had home-range sizes intermediate to those of juveniles and pups (Figure 4). Parental investment into pup survival by the Beechridge breeders through pup attendance may have restricted their complete use of the pack's territory and, as a result, may have contributed to them having home-range sizes intermediate to those of juveniles and pups. Beechridge breeders and non-breeders did not differ in night home-range sizes. Such data may indicate shared foraging effort by breeders and non-breeders in red wolf packs during the pup rearing season.

In contrast to finding no change in adult and juvenile night home-range sizes from day home ranges, pups consolidated at night and had statistically smaller home-range sizes than during the day (Figure 4). Because pups are not actively foraging with adults and juveniles, they may consolidate to core areas and/or rendezvous sites within the packs home range for security reasons and to wait for possible feeding opportunities. During the day, it is possible that red wolf pups are actively moving about the territory while adults and juveniles take turns resting and monitoring the pups. The overall smaller home ranges of pups versus adults and juveniles indicate that red wolf pups may require more than 20 weeks to acquire the ability to fully utilize the pack's territory.

The Beechridge and Ransomville territories had similar habitat composition and both packs centered their activities on the relatively large agricultural tracts of corn, cotton, and soybean fields, but they differed in their use of cotton fields and soybean fields (Table 2, Figure 2). The Ransomville pair used cotton and soybean fields proportional to their availability, while this trend was not seen in the Beechridge pack. Because the Beechridge pack utilized cornfields as rendezvous sites for their pups, it is reasonable that more time was spent by Beechridge individuals in these cornfields while caring for and feeding pups.

Despite differences in use of cotton fields and corn fields, diurnal and nocturnal uses of habitats were similar for both packs. Corn fields typically made up most of the core areas for both packs and red wolves seemed to radiate out of them at night to use the surrounding cotton and soybean fields to forage for potential prey. However, cotton was also used as resting areas for red wolves during the day.

Red wolves display dramatic seasonal fluctuations in habitat use by utilizing woodlots during the fall and winter and then switching to agricultural fields during the spring and summer (Unpublished data, Red Wolf Recovery Program). Similar shifts from woodlots in the fall and winter to extensive use of agricultural fields in the spring and summer have been documented in eastern coyotes and foxes (Person and Hirth 1991; Holzman et al. 1992; Chamberlain et al. 2000; Gosselink et al. 2003). Such changes in habitat use and shifts in home ranges may be reflect the use of habitats that offer vital cover during the non-growing season and use of crop fields during the spring and summer in order to take advantage of increases of prey density (Gosselink et al. 2003). However, other hypotheses as to why red wolves would prefer agricultural croplands over adjacent woodlots during the summer can be considered for testing.

The extensive incorporation of croplands into red wolf habitat may be influenced by food availability, but it is possible that avoidance of woodlots may be a result of favoring agricultural tracts due to favorable micro-climate. Summers in northeastern North Carolina are hot and humid. Invertebrate pests and parasites, such as nematodes, biting flies, ticks, and mosquitoes, are common. These pests and parasites are considered a nuisance by many of the horse and livestock owners in the area. Because crop fields are often sprayed with insecticide, pest and parasite levels in crop fields are likely to be lower than in the surrounding woodlots. Red wolves preference for crop fields may be a result of lower invertebrate levels. Red wolf energy balance may be negatively affected by insect harassment because biting insects are known to be vectors for diseases and internal parasites (Walsh et al. 1992). By utilizing crop fields during the summer months red wolves may increase survival by lowering disease and internal parasite loads by avoiding areas of high biting insect and tick densities. Additionally, crops planted in dense rows, such as corn, cotton, and soybean, provide strong shade, lack dense understories, and maintain strong wind tunnels that may alleviate the effects of summer heat and humidity and help red wolves thermoregulate.

Agricultural fields may provide more suitable habitat for red wolves because the simple and uniform structure of crop fields allow them to possess the site-specific serial motor programs that make using their home ranges equivalent to near reflex movements (Stamps 1995). By establishing territories in agricultural fields red wolves maybe able to take advantage of such predictability to aid in the acquisition of resources and security.

Knowing activity patterns of humans and of prey in very simple and homogeneous structured habitat such as row crop fields may allow wolves to know their territory more intimately than they would if they utilized the heterogeneous habitats of the surrounding woodlots.

**Management Implications**

Hybridization is considered to be the primary threat to the recovery of red wolves in northeastern North Carolina (Kelly et al. 1999; Stoskopf et al. 2005). Recent DNA profiles that indicate a common lineage between red wolves and coyotes may explain why red wolves readily hybridize with coyotes (Wilson et al. 2000). Results from this study imply that red wolves, like eastern coyotes, show strong preferences for agricultural croplands. This insight may allow biologists to predict were hybridization events are occurring within the Recovery Area. It also raises questions as to whether red wolf and coyote hybridization events are natural or anthropogenic in origin and source.

In the face of increasingly human altered landscapes and expanding coyote populations, managing red wolves will require sound management planning (Stoskopf et al. 2005). By focusing on red wolf-habitat relationships, Recovery Program biologists could begin to focus on natural components that contribute most to species survival. Key insights into red wolf home range and habitat use will contribute to developing sound management procedures to avoid admixture of the two species. Results from this study show that the spatial ecology of red wolves deserve further study because red wolves and coyotes historically did not coexist in the southeast, an appropriate step in resolving the hybridization problem would be to identify and understand what components in the environment allow for red wolves and coyotes to be sympatric.

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Table 2.1: 95% kernel density home range estimates ($km^2$) of red wolves in northeastern North Carolina during the pup rearing season. Three estimates are given, based on all location data, day locations only, and night locations only.

| | | | | | | Home Range Size ($km^2$) | | |
|---|---|---|---|---|---|---|---|---|
| Wolf | Sex | Age | Social Status | Pack | No. of Locations | All Locations | Day Locations | Night Locations |
| 11162 | F | Adult | Breeder | Beechridge | 108 | 76.4 | 92.5 | 86.4 |
| 11199 | M | Adult | Breeder | Beechridge | 106 | 69.1 | 57.5 | 99.3 |
| 11327 | M | Juvenile | Non-Breeder | Beechridge | 114 | 69.1 | 71.2 | 73.9 |
| 11328 | F | Juvenile | Non-Breeder | Beechridge | 108 | 87.0 | 76.2 | 101.1 |
| 11424 | M | Pup | Pup | Beechridge | 110 | 61.3 | 64.8 | 51.4 |
| 11427 | M | Pup | Pup | Beechridge | 107 | 64.8 | 65.5 | 48.0 |
| 11428 | F | Pup | Pup | Beechridge | 107 | 60.8 | 64.7 | 50.4 |
| 11431 | M | Pup | Pup | Beechridge | 106 | 59.0 | 61.8 | 50.6 |
| 11049 | F | Adult | Non-Breeder | Ransomville | 88 | 82.9 | 64.7 | 88.2 |
| 11310 | M | Juvenile | Non-Breeder | Ransomville | 86 | 110.6 | 112.0 | 105.7 |

Table 2.2: Conclusions on preference and/or avoidance of the Beechridge pack and Ransomville pair for the five defined types of habitat available.

| Wolf | Pack | $\chi^2$ | df | P-Value | Corn | Cotton | Soybean | Woodlot | Other |
|---|---|---|---|---|---|---|---|---|---|
| 11162F | Beechridge | 34.6 | 4 | <0.0001 | Prefer | | Avoid | Avoid | Avoid |
| 11199M | Beechridge | 60.5 | 4 | <0.0001 | Prefer | Avoid | Avoid | Avoid | Avoid |
| 11327M | Beechridge | 67.2 | 4 | <0.0001 | Prefer | | Avoid | Avoid | Avoid |
| 11328F | Beechridge | 57.0 | 4 | <0.0001 | Prefer | Avoid | Avoid | Avoid | Avoid |
| 11424M | Beechridge | 49.2 | 4 | <0.0001 | Prefer | Prefer | Avoid | Avoid | Avoid |
| 11427M | Beechridge | 49.2 | 4 | <0.0001 | Prefer | | Avoid | Avoid | Avoid |
| 11428F | Beechridge | 51.0 | 4 | <0.0001 | Prefer | | Avoid | Avoid | Avoid |
| 11431M | Beechridge | 45.3 | 4 | <0.0001 | Prefer | Prefer | Avoid | Avoid | Avoid |
| 11049F | Ransomville | 45.3 | 4 | <0.0001 | Prefer | | | Avoid | Avoid |
| 11310M | Ransomville | 34.3 | 4 | <0.0001 | Prefer | | | Avoid | Avoid |
| Combined | | 493.6 | 40 | | | | | | |

Table 2.3: Bonferroni confidence intervals for the proportion of locations found in each habitat type for red wolves. Habitats showing percentages lower than their corresponding confidence interval were used significantly more often than their availability, percentages within the habitat's confidence interval were used in proportion to their availability, and habitats with percentages larger than their confidence interval were used significantly less often than their availability.

| Habitat Type | # of Locations | % of Habitat | Confidence Interval |
|---|---|---|---|
| Corn | 594 | 0.199 | $0.549 \leq p_{corn} \leq 0.609$ |
| Cotton | 311 | 0.199 | $0.276 \leq p_{cotton} \leq 0.332$ |
| Soybean | 105 | 0.299 | $0.085 \leq p_{soybean} \leq 0.122$ |
| Woodlot | 8 | 0.233 | $0.004 \leq p_{woodlot} \leq 0.015$ |
| Other | 8 | 0.070 | $0.004 \leq p_{other} \leq 0.015$ |

Figure 2.1: Percent of habitat type found in minimum convex polygon home range estimates for the Beechridge pack and Ransomville pair during the pup rearing season.

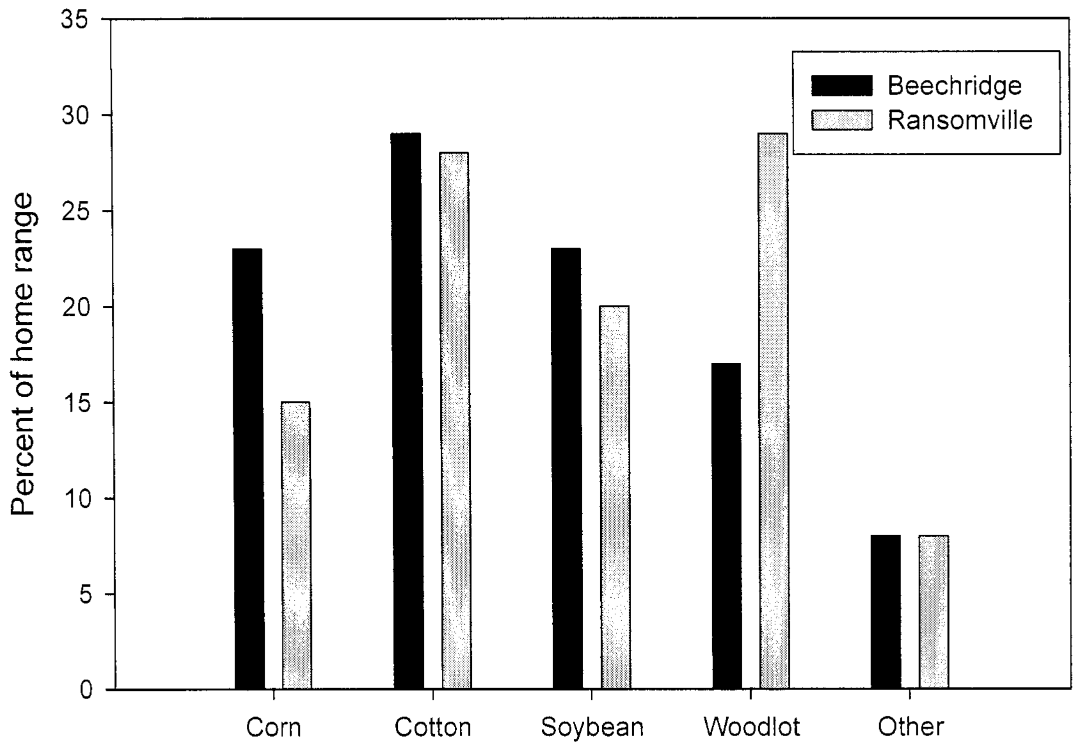


Figure 2.2: Percent of habitat used by individual red wolves at two study areas in northeastern North Carolina during one pup rearing season (July 2005 to September 2005).

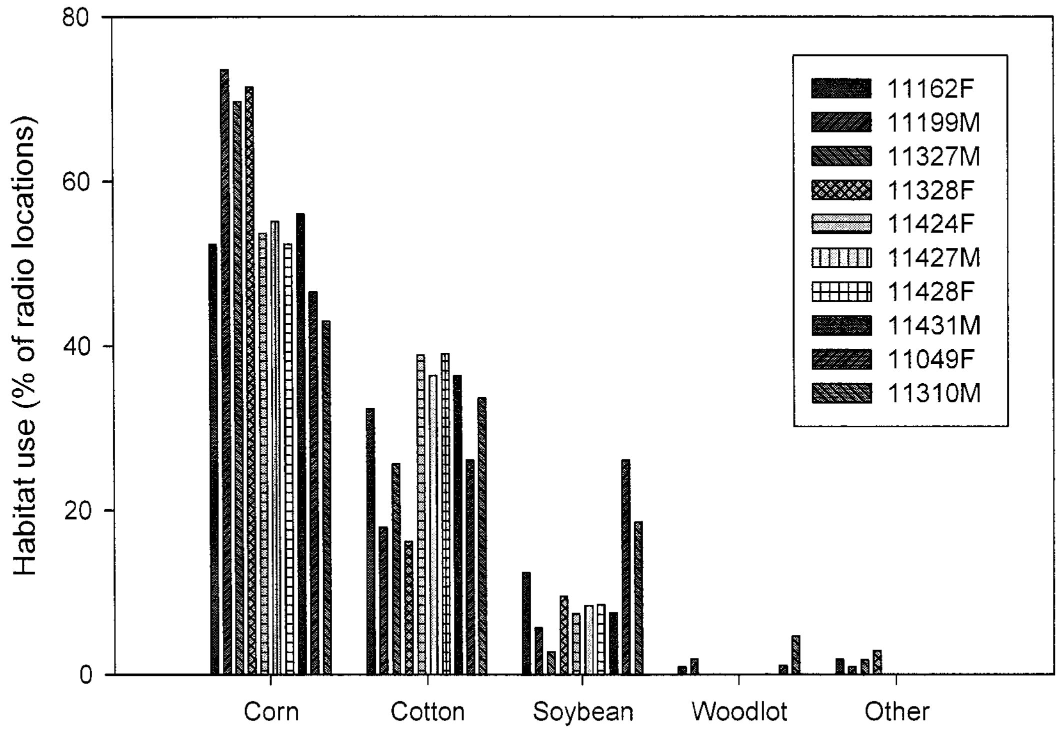


Figure 2.3: Mean home range size (km²) of the Ransomville pair and Beechridge pack during the pup rearing season. Vertical bars indicate standard error.

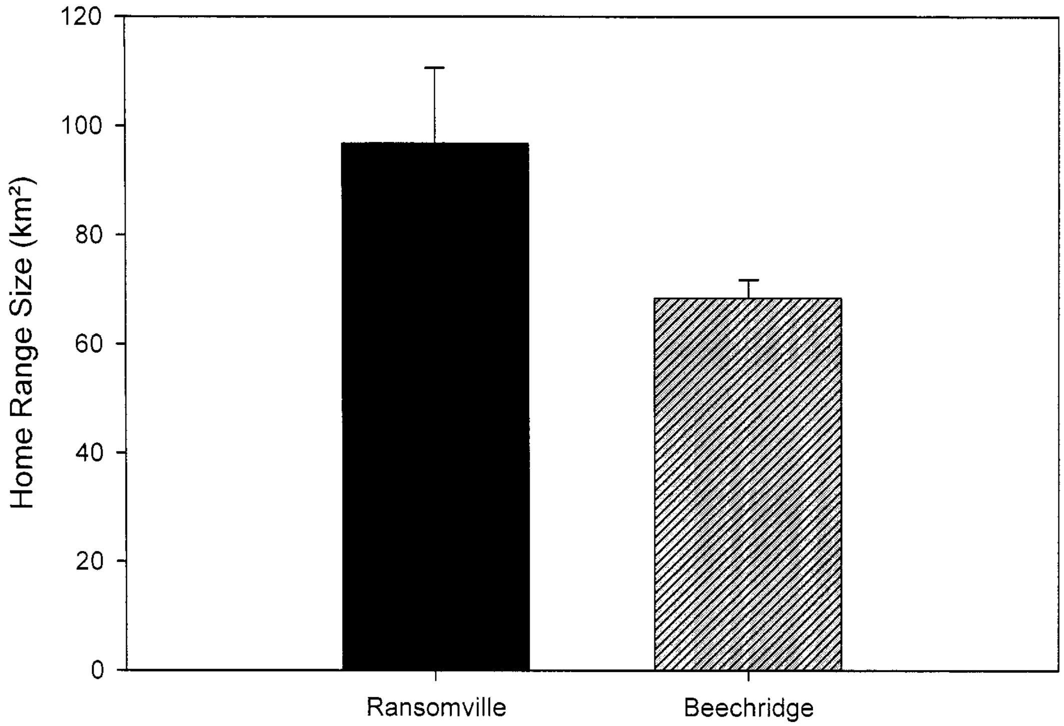
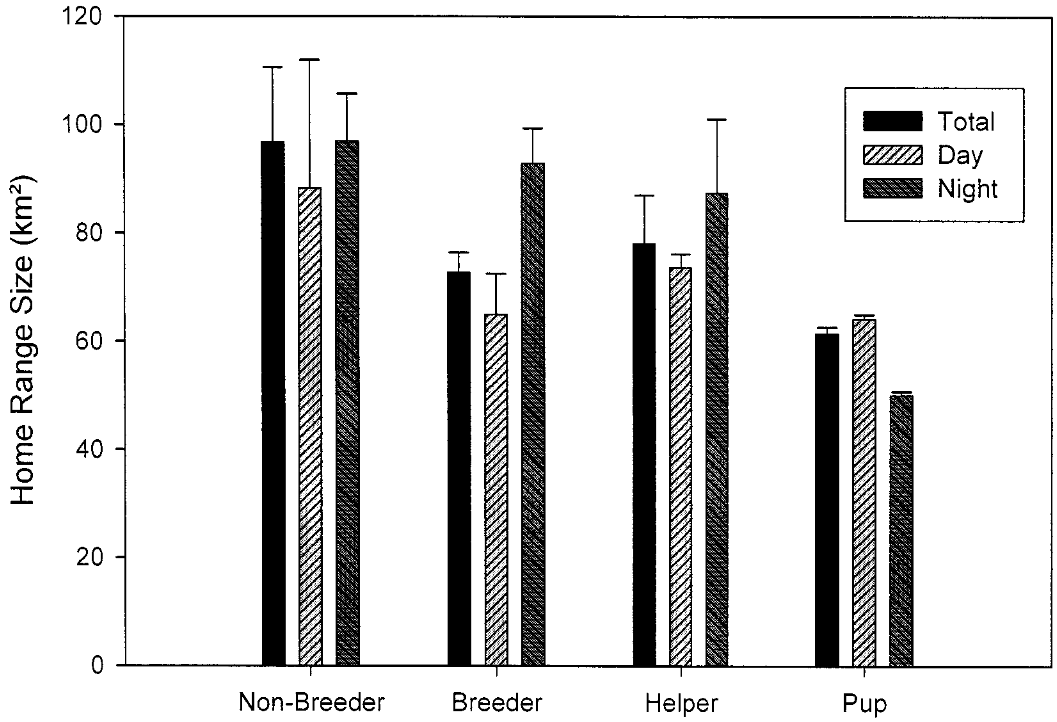


Figure 2.4: Total (all radio locations), diurnal (day radio locations), and nocturnal (night radio locations) home range sizes (km²) of red wolves by social status. Vertical bars indicate standard error.



# Chapter 3

## Using Abdominal Transmitters in Pups to Gain Insights into Red Wolf (*Canis rufus*) Pup Rearing: A Pilot Study


### Abstract

Identifying the critical factors causing mortality in red wolf pups has been an important issue for the Red Wolf Recovery Program because the reintroduction of red wolves into the Great Smoky Mountains National Park was terminated as a result of high pup mortality. Currently, the reintroduced red wolf population in northeastern North Carolina is expanding, however, little is known about pup survivorship in red wolves and what ecological factors determine rates of mortality. To evaluate red wolf pup rearing in northeastern North Carolina, we conducted a pilot study to evaluate the effectiveness of using abdominal transmitters to monitor pup activity. Pup surgically implanted with abdominal transmitters showed similar changes in weight as did non-transmittered pups and there were no mortalities in transmittered pups. Results show that abdominal transmitters are a feasible method to monitor red wolf pups before they reach the minimum size to safely wear radio-collars. Data indicated that red wolves may abandon woodland dens early to move pups into adjacent agricultural fields. Red wolves used multiple rendezvous sites throughout the pup rearing season. Consistent with other pup rearing studies done on gray wolves, red wolf yearling and breeding females attend pups more frequently than do yearling and breeding males. Red wolf pups are rarely left alone indicating the red wolves share duties of pup rearing and that males play a significant role in the rearing of red wolf pups.


**Key Words:** Red wolf, *Canis rufus*, abdominal transmitters, pup attendance.

**Introduction**

The large number of works published on the subject of pup rearing in North American *Canis* is proof that it is an important issue for wolf biology, management, and conservation (Mech 1970; Bechoff 1978; Andelt et al. 1979; Harrington and Mech 1982; Harrington et al. 1983; Harrison and Gilbert 1985; Gese 2001; Potvin et al. 2004). One of the difficulties in obtaining unbiased survival data for wolf pups is the inability to extensively monitor wild pups during their first year of life because of problems associated with keeping rapidly growing pups equipped with radiotransmitters. Consequently, the ecological determinants of pup mortality during the pup rearing season are one of the least understood areas of wolf biology (Keith 1978; Fuller et al. 2003) despite the large number of studies that have examined pack dynamics during the pup rearing season. The first six months have been documented to be a critical time for wolf pups and survival rates vary greatly (Ballard et al. 1987; Fuller 1989).

In red wolves (*Canis* rufus) particularly, identifying the timing and causes of mortality in pups in the wild has proven to be very difficult. Wagener (1998) studied the ontogeny of red wolf (*Canis rufus*) social behavior in captivity with the goal of finding species specific behavioral patterns. To date, this is the only published effort to understand pup rearing behavior in red wolves. Early field work by Paradiso and Nowak (1972) showed that red wolves had high levels of pup mortality on the Texas Gulf Coast in the late 1960s, with most pups dying before six months of age. It was hypothesized that marginal habitat, high parasitic loads, and the inability of red wolves to form packs were the primary causes of red wolf pup mortality.

The reintroduction of red wolves in the Great Smoky Mountains National Park (GSMNP) was terminated as a result of red wolves failing to establish home ranges within GSMNP and the high mortality of red wolf pups. Of 37 released red wolves, 26 were later found to have strayed off GSMNP and onto adjacent private lands and the 28 pups known to be born in the wild suffered unknown fates within their first year (Lucash and Crawford 1998). Although the Recovery Program biologists noted that one pack lost its pups to parvovirus and another pack had its litter killed by coyotes (Lucash and Crawford 1998), the inability to find and retrieve pup carcasses made it difficult for the Recovery Program to assess causes of death for red wolf pups. It is also thought that the difficulty that red wolves had in establishing home ranges in GSMNP hindered the formation of packs which would aid breeders in the successful rearing of young.

Despite the difficulties encountered during the GSMNP project, the Alligator River National Wildlife Refuge (ARNWR) project in northeastern North Carolina (NENC) has been a strong success. Currently, red wolves in NENC are establishing territories and successively rearing pups in the wild and the current population is expanding. Also, several of the founder packs, such as Milltail, Gator, and Airport are approximately 20 years old. However, survivorship of red wolf pups in the NENC population varies across the expanding population. As a result, one of the Recovery Program's objectives of the 2005 and future pup rearing seasons is to evaluate a method using abdominal transmitters that would allow more efficient monitoring of wild red wolf pups.

The traditional mode of monitoring red wolves has been the use of VHF radio-collars on adult and juvenile wolves. During the initial phases of the reintroduction project in ARNWR, Recovery Program biologists fitted several pups at 10 weeks of age with abdominal transmitters to ensure that family units released into the wild stayed together (Phillips 2003). Data from transmittered pups were collected for management objectives only. Once biologists were confident red wolf family units remained together when released into the wild, use of abdominal transmitters stopped. Currently, red wolf pups are not radio-tracked and abdominal transmitters are typically used as a back up transmitter when testing the effectiveness of GPS collars.

The effectiveness of abdominal transmitters to be used as a monitoring technique for red wolf pups is unknown. In concert to the additional trauma of surgically implanting transmitters in red wolf pups, short battery life and the dampening effect of body size on signal transmission cause biologists to avoid using abdominal transmitters. However, other studies have noted the success of procedures using abdominal transmitters to gather important ecological data for animals that are not capable of being fitted with radio-collars such as beavers (Davis et al. 1984; Guynn et al. 1987; McNew and Woolf 2005), otters (Garshelis and Siniff 1983; Hernandez-Divers et al. 2001), bears (Philo et al. 1981; Koehler et al. 2001), and birds (Klugman and Fuller 1990; Olsen et al. 1992; Lewis et al. 2005). Many of these studies reported no discernable effect to foraging, pregnancy rates, productivity, and defense of territories.

The objectives of this study were to investigate a method that would allow more efficient monitoring of wild red wolf packs and to increase knowledge in a poorly known area in red wolf ecology. To evaluate the effectiveness of using abdominal transmitters to recovery pup carcasses in field, four pups of the Beechridge pack were surgically radio-tagged. Since pups could be radio-tracked in the field, data was also collected in an attempt to monitor red wolf pup rearing behavior. Although questions and motives of the study were primarily motivated by a management needs, the results could provide insights into the cooperative breeding, parental-offspring relationships, and offspring survivorship in large carnivores.

**Study Area**

The Red Wolf Recovery Area in northeastern North Carolina currently contains the only wild, free roaming population of red wolves. The five counties (Beaufort, Dare, Hyde, Tyrrell, and Washington) that the Recovery Area is located in are made up of federal, state, and private land, which is divided into three management zones that total to approximately 607,041 hectares. All individual red wolves monitored in this study were found in Beaufort County, which is located in the southwestern portion of the Recovery Area, approximately 35°N, 76°W. Northeastern North Carolina has four full seasons and is typical of the mid-Atlantic climate. Annual precipitation averages between 122 to 132 centimeters. Summers are typically hot and humid with temperatures ranging from 27°C to 38°C. Although there are several incidents of snowfall, winters are relatively cool and wet with temperature ranges of -4°C to 7°C. For this study, data collection occurred from mid-July 2005 until mid-September 2005 from red wolves located on private agriculture tracks just outside of Pocosin Lakes National Wildlife Refuge (PLNWR).

Despite the many types of habitats within the Recovery Area such as, pocosin forest, mixed pine-oak forest, gum swamp, pine plantations, saltwater marsh, and agricultural fields, the red wolves in this study used agricultural fields, commercially managed loblolly pine (*Pinus taeda*), and mixed pine-hardwood forests. The agricultural landscape was made up of corn (*Zea mays*) fields, soybean (*Glycine max*) fields, cotton

(*Gossypium sturtianum*) fields, and livestock pastures (cattle and hog ranches). Mixed pine-oak forests were composed of a number of tree species such as, pines (*Pinus* spp.), oaks (*Quercus* spp.), maples (*Acer* spp.) and hickories (*Carya* spp.), while the understory of these forests were mostly of hawthorns (*Crataegus* spp.), bayberries (*Myrica* spp.), hollies (*Ilex* spp.), greenbrier (*Smilax* spp.), fox grape (*Vitas labrusca*), trumpet-creeper (*Campsis radicans*), and Virginia creeper (*Parthenocissus quinquefolia*).

**Methods**

In order to maintain effective monitoring of red wolves, Recovery Program biologists trap and monitor, via radio-telemetry, nearly all wild free roaming red wolf individuals and family groups in northeastern North Carolina (USFWS 1989). Locating individual red wolves twice a week by air is the primary monitoring method used by the Recovery Program. Both adults and juveniles in the Beechridge pack were captured and radio tagged prior to this study for monitoring purposes. During the 2005 whelping season the breeding female gave birth to a litter of nine pups, of which four had transmitters surgically implanted into their abdominal cavity.

Monitoring the adults, juveniles, and four of the pups for the 2005 pup rearing season allowed the Recovery Program to weigh the costs and benefits of monitoring individuals of all age classes in the red wolf population. One pack of red wolves and a pair of non-breeders were studied during the months of July, August, and September 2005 to examine parental investment into pup survival by pack members. To capture adult and juvenile red wolves, Recovery Program biologists use steel, leg-hold traps with padded, offset jaws to live capture red wolves. Although red wolves younger than nine months of age are usually not radio tagged because of the dramatic weight changes and changes in head and neck girths due to growth rates, four pups of the Beechridge pack were captured to be surgically fitted with transmitters. Recovery Program biologists captured red wolf pups by foot pursuit and securing them using salmon nets to fit them with abdominal transmitters.

Veterinarian Anne Acton of North Carolina State University volunteered her service to implant abdominal transmitters into red wolf pups at the capture site. Initial anesthetic induction was achieved in individual red wolf pups by placement in a chamber with 5% isoflurane ($O_2$ flow rate 3L/min). General anesthesia was maintained during surgery using a Norman elbow rebreather and small mask with 2-2.5% isoflurane ($O_2$ flow rate 1L/min). Pups were monitored using a pulse oximeter, rectal thermometer, and a stethoscope. Each pup received butorphanol subcutaneously (0.3 mg/kg) pre-operatively and cephazolin (20 mg/kg) IM for pain control and antibiotics, respectively. Surgical preparation included minimal hair clipping of the immediate surgical field to minimize heat loss. Following pre-surgical preparation, a ventral midline skin incision ~3cm was made ~1cm caudal to umbilicus using a #15 blade. The incision was carried through the linea alba to enter the abdominal cavity. Prior to placement, the gas-sterilized transmitter was tested with a radio receiver for signal and then rinsed with sterile saline. The transmitter (ATS, Isanti, Minnesota) was inserted through the abdominal incision parallel to the body wall. Transmitters were allowed to float freely within the abdominal cavity. A simple interrupted subcuticular pattern with 3-0 polydioxanone (PDS) suture was utilized to perform a two layer closure. The average time of the total procedure (anesthesia induction to incision closure) lasted approximately 25 minutes. Speed increased with successive pups. The surgery time took approximately 15 minutes.

Anesthesia was turned off and pups were provided with oxygen for several minutes until purposeful movement returned. Pups continued to recover quietly in a dark crate with litter mates and cleared for release to the capture site once they were able to achieve sternal recumbancy and could hold their heads up. Average recovery after surgery was approximately 5-10 minutes. Pups were separated from parents for about 4-5 hours.

Radio-collared wolves were systematically located 1-5 times during a 12 hour shift on a daily basis using a receiver and a 6-element Yagi antenna (Telonics, Inc., Mesa, AZ.) mounted on a vehicle. Radio-collars hung from nearby fire towers were used as beacons to orient compass rose prior to field triangulation of radio-tracked wolves. Sequential locations were separated by more than two hours. Diurnal and nocturnal monitoring alternated on a weekly basis. All individual red wolf locations were estimated from triangulation methods in the field that used more than three compass bearings with intersecting angles between 20° and 160° recorded in less than 15 minutes. Telemetry error was determined by reference collars and transmitters to be ±2.5° for both. Mean error for reference collars and transmitters were 11.79m and 19.22m, respectively. Universal Transverse Mercator (UTM) coordinates and compass bearings from the field triangulations were imported into LOCATE III (LOCATE, Tatamagouche, NS, Canada) to estimate individual red wolf locations in 5-digit easting and 6-digit northing UTM coordinates. ArcCatalog (ESRI, Redlands, California) was used to generate point shapefiles for the wolf datasets. Individual red wolf location point shapefiles were imported into ArcView 3.2 (ESRI, Redlands, California) and ArcView 9.1 (ESRI, Redlands, California) to analyze spatial data using the Animal Movement 2.2 extension. ANOVA and chi-square tests were used to analyze spatial data.

**Results**

Two adult and two juvenile red wolves (two male, two female) of the Beechridge pack were known to be attending nine pups from the 2005 pup rearing season. Two adults, two juveniles, and four pups of this pack were radio-monitored from July 2005 through mid-September 2005, resulting in 914 telemetry locations. During the pup rearing season, a non-breeding pair of red wolves was also monitored. From mid-July to mid-September during the 2005 pup rearing season 1042 estimated locations for 10 wolves were obtained. Throughout the study season, 95.77 % of the 1088 total attempts that were made to locate all 10 wolves were successful. Of these estimated locations, only 3% of them were visual confirmations. The percentage of failed attempts to locate individual wolves did not differ between radio-collars and abdominal transmitters ($F_{1, 1024} = 0.07$, $P = 0.7943$). However, there was a significant difference in the size of error polygons ($F_{1, 1024} = 20.26$, $P = 0.002$). Mean error polygons for radio-collars were larger ($2.191 \pm 0.305$ km$^2$) than those for abdominal transmitters ($1.482 \pm 0.058$ km$^2$). Although error polygons for radio-collars were not influenced by habitat type ($F_{4, 598} = 1.69$, $P = 0.1672$), habitat type did influence the size of error polygons for abdominal transmitters ($F_{2, 424} = 22.85$, $P < 0.0001$).

During the 2005 winter trapping period, Recovery Program biologists captured eight of the nine Beechridge pups between January 21, 2005 and January 29, 2005. It is assumed that one pup died during the pup rearing season. The transmittered pups weighed an average of 26 kg (Table 1). The four non-transmittered pups' weights averaged 21 kg. Transmitters were found not to have influenced pup weight ($F_{1, 6} = 2.17$, P = 0.1916). Recovery Program biologists palpated the abdomens of the transmittered pups and successfully removed the transmitters.

The Beechridge pack abandoned their den when pups were about four weeks of age and moved them into adjacent agricultural fields where four pups were caught and had transmitters implanted. After the Beechridge pack abandoned their den, they concentrated their activity around three rendezvous sites in corn and cotton fields. Pups concentrated their activity at these rendezvous sites and continued to use them heavily throughout the duration of the study.

Previous studies that examined homesite attendance patterns of coyotes and wolves have varied in the distances to dens and homesites that were used as indicators of attendance. Andelt et al. (1979) considered locations within 200m of the den as being in attendance. Harrison and Gilbert (1985) chose to use a 300m radius and any locations found within it were considered attendance. Coyotes in their study were found to be inactive around 200-300m from the den and were assumed to be resting and attending the pups. Potvin et al. (2004) when studying proximity of wolves to homesites used a radius of 250m to define attendance. What is common among all of these studies was that the relevant distance varied depending on how habitat structure limited visual observations by pack members. Harrison and Gilbert (1985) noted a potential bias in arbitrarily defining areas around dens to calculate attendance occurs when different radii are used to define attendance because it creates substantial differences in estimated attendance rates.

For this study, attendance was assumed to occur when wolves were within 250m of one of the four transmittered pups. Defining attendance as 250m was done by observing the frequency distribution of adult and juvenile mean distances to the pups in

100m increments (Figure 1). The highest peak occurred at the 200-300m range, but dropped off suddenly at the 400-500m range. To be consistent with the literature and to be conservative, attendance was assumed to occur at distances less than 250m to the pups. Additionally, distances from pack members were compared to the distances that the non-breeding Ransomville pair were from each other (Figure 6). The Beechridge pack were found to be in closer proximity to each other when compared to the Ransomville pair ($\chi^2 = 72.63$, df = 4, $P < 0.0001$). Observing higher percentages of locations that Beechridge pack members were to each other at the 250-500m range when compared to the Ransomville pair indicated that attendance may be occurring at the 200-300m range.

The spatial relationships of the Beechridge pack were monitored for approximately eight weeks (Table 2 and 3). Adults and juveniles centered their activity near rendezvous sites where the pups could be located. Mean distance from pups for adults and juveniles were 586m and 661m, respectively. ANOVA (Table 4) indicated little difference between day and night mean estimated distances of adults and juveniles from pups ($F_{1, 399} = 0.01$, $P = 0.9467$). However, pups were closer to each other at night than during the day ($F_{1, 406} = 8.16$, $P = 0.0045$). Although there was an increasing trend of mean estimated distances from pups from July to September by adults and juveniles, mean estimated distance of adults and juveniles from pups did not differ among months ($F_{2, 398} = 0.93$, $P = 0.3958$). The opposite was found when comparing mean estimated distances of pups from other pups. Red wolf pups were found to statistically increase their mean estimated distance from each other as the season progressed (Table 5).

Mean estimated distances did not appear to depend on the reproductive status (Figure 2), although pups were closer to each other than they were to other members of the Beechridge pack. Adults and juveniles were not statistically different in their estimated distances from pups ($F_{1, 399} = 1.65$, $P = 0.1994$). Additionally, differences between mean estimated distances from pups by wolf sex was slightly rejected ($F_{1, 399} = 3.05$, $P = 0.0814$), despite the visual differences indicating males were found closer to pups at the 0-250m range than were females (Figure 3). Habitat type was shown to have an influence on the distances that Beechridge members were found from the pups ($F_{4, 396} = 6.79$, $P = 0.0002$) indicating that habitat structure may influence observational distances from pups.

Chi-square analysis was conducted to investigate the influence that sallies and foraging bouts may have had on using mean estimated distances from pups (Table 6). Attendances of individual wolves were counted when an estimated location was found within 250m of any transmittered pup. This was also done to examine attendance by sex, age, part of day, and month. Chi-square analysis showed statistical differences in attendance by individual wolves ($\chi^2 = 12.88$, df = 3, $P = 0.0049$) in which 11162F (breeder) was found attending pups more often than other members. Females attended pups more often than males ($\chi^2 = 7.47$, df = 1, $P = 0.0063$) and adults were found to be with pups more often than juveniles ($\chi^2 = 11.41$, df = 1, $P = 0.0007$). Additionally, red wolves were found to be attending pups more often during the day than at night ($\chi^2 = 9.01$, df = 1, $P = 0.0027$). No significant difference in attendance was found among months ($\chi^2 = 5.01$, df = 2, $P = 0.0817$) despite the decreasing trend observed in attendance as pups increased in age.

Pups were rarely found alone. 77% of the time, red wolf pups were found within 250m of older pack members (Figure 4). Sixty-three percent of the adult locations were found to be within 250m of a red wolf pup and 47% of juvenile locations were within 250m of a pup. Additionally, a larger proportion of female locations were found to within 250m of pups than were males (25% to 12%). However, 39% of attendance by sex was simultaneous, in which pups were found being attended by both sexes (Figure 5).

**Discussion**

This study has quantified previously unknown spatial relationships between red wolf pack members and pups during the pup rearing season. Without the use of abdominal transmitters in red wolf pups, the acquisition of such data would not have been possible. Although there are known disadvantages to using abdominal transmitters such as limited range, body size influence on signals, and a short battery life, use of implants in red wolf pups will enhance monitoring and management of red wolves in northeastern North Carolina.

Several reasons make using implants practical in the red wolf population. First, the red wolf population is highly accessible to researchers because of the high density of hard and soft roads throughout the study area. Evidence of this was the high success (95.77%) of finding and estimating red wolf locations. Secondly, red wolves use agricultural tracts where they became acclimated to the human activities related to farm work. This allows researchers to monitor wolves in close enough proximity as to not influence their behavior and record accurate locations via mounted antenna on vehicles. Most importantly, implants will allow Recovery Program biologists to find and recover pup carcasses in time to conduct accurate necropsies that will lead to insights into red wolf demographics.

Most authors have contended that events at home sites can determine pup survival and the reproductive status of wolf packs (Van Ballenberghe and Mech 1975; Harrington et al. 1982; Harrington and Mech 1995; Potvin et al. 2004); it is probably the reason why most studies have centered data collection of pup rearing around home sites and used distances of pack members to home sites as a measurement of attendance. However, this method is not practical in studying pup rearing in wild red wolves. The dense vegetation that red wolves prefer prevents accurate visual observations of behavior as shown by only 3% of the estimated locations taken during the pup rearing season being visual confirmations.

Red wolves abandon dens in woodlots shortly after whelping and move their pups into agricultural fields such as corn and, later, cotton. The Beechridge pack abandoned their den in a woodlot and moved pups at four weeks of age into adjacent corn fields approximately 1,600m away. Throughout the summer, the Beechridge pack used three rendezvous sites within their territory and, at times, multiple rendezvous sites were used simultaneously with transmittered pups being split among the sites. Red wolf behavior and the type of habitat they exist in make using the traditional method problematic. It is also interesting to note that abandoning dens early and rotating use among several rendezvous sites may be advantageous to red wolves because heavy accumulation of ticks, fleas, mosquitoes, and other potential parasites in bedding areas may lower pup survival. Utilizing multiple rendezvous sites to reduce parasite loads may be favorable during the pup rearing season in the hot and humid climate of northeastern North Carolina.

Delineating when and where attendance is occurring through spatial relationships to the home site is problematic because researchers cannot conclude what the motivation of the wolf is at the home site. Harrington et al. (1982) hypothesized that juveniles may take advantage of home sites as a way to exploit a consistent food resources and may hinder pup development through competition. Potvin et al. (2004) also hypothesized that juveniles may not be fully capable of fending for themselves and may need additional time to learn how to hunt and survive on their own. Implanting abdominal transmitters into red wolf pups proved to be a better method of quantifying pup rearing in red wolves because it allowed measuring the spatial relationships of pack members to pups independent of home site. It also allowed the collection of data on red wolf pups that would not be possible if they were not radio tracked, such as home range size and habitat use, which could give further insights into pup rearing.

I observed several significant patterns throughout the pup rearing season. First, attendance of red wolf pups was highest during the day light hours. Although there was no significant difference found between mean distances to pups between night and day estimated locations, the probability that a Beechridge pack member would be found within the estimated attendance perimeter of the pups was higher during the day. This pattern was also found by Potvin et al. (2004) during their study of Isle Royale wolves. The lower frequency of attendance by red wolves at night may be an indication of foraging effort (Harrington et al. 1982). Additionally, red wolf pups were found to consolidate to rendezvous sites at night, which may also indicate they may be waiting for food and/or congregating for security.

Although red wolf pups were found to increase their distances from each other as they aged, frequency of attendance to pups by Beechridge pack members did not change as pups aged. Differences in attendance to pups by red wolves from July to September was not large enough to be statistically significant ($P = 0.0817$). Other studies have shown that attendance rates and distances traveled increase as wolf pups became older (Harrington and Mech 1982; Ballard et al. 1991; Theuerkauf et al. 2003; Potvin et al. 2004) and have concluded that as pups grow, their dietary requirements increase causing pack members to forage at greater distances and longer periods. The similarity in distances and attendance among months may be a result of a hog burial pit being located adjacent to the pack's territory. Beechridge pack members, including pups, were located near the pit. On several occasions, both females were observed entering and exiting the pit when fresh hogs carcasses were deposited there. Also, there were numerous signs, such as tracks and scat at the pit and parts of buried hogs at rendezvous sites indicating frequent visits to the hog pit. Alternative food resources could curb red wolf foraging bouts.

Consistent with Wagener's (1998) observations of captive red wolves and with other wolf and coyote pup rearing studies, Beechridge yearling and breeding males attended pups less frequently than did the yearling and breeding females (Mech 1970; Andelt et al. 1979; Harrington et al. 1982; Harrison et al. 1985; Ballard et al. 1991; Potvin et al. 2004). However, as indicated for gray wolves in Potvin et al. (2004), red wolves were observed to be simultaneously attending pups at high rates, in which red wolf pups were only found alone 24% of the time. This may indicate that red wolves attend pups as groups rather than single individuals. Red wolves may attend pups at short and rapid intervals. The high density of black bears in northeastern North Carolina and the extensive use of agricultural fields by black bears may pose a similar threat to red wolf pups as seen in other wolf pup rearing studies and the attendance patterns during the day may be correlated with the diurnal activities of black bears (Potvin et al. 2004).

In conclusion, the current pilot study was limited in scope, but the preliminary findings related to the investment in rearing red wolf pups represent the only data on red wolf pup rearing in the wild. Patterns seen in wild red wolves corroborate results of Wagener's (1998) study and other studies of gray wolves indicating the importance of parental investment into pup rearing and the significant contribution male wolves have in the development of pups. It also indicates that parent-offspring interactions deserve further study that should include field experiments to compliment the traditional observation methods of studying pack dynamics.

**Management Implications**

Identifying the timing of mortality in red wolf pups has been an important issue to the Recovery Program. Paradiso and Nowak (1972) observed high mortality in red wolf pups prior to the removal from the wild and the GSMNP project was terminated as a result of high pup mortality. The inability to retrieve pup carcasses makes it difficult for Recovery Program biologists to assess the causes of mortality in red wolf pups. Although none of the four transmittered pups died during the study, valuable spatial data was gathered on red wolf behavior during the pup rearing season.

Understanding wolf movement patterns and habitat preferences during the pup rearing season may provide insights into what factors influence successful pup rearing by wild red wolves. Data from this pilot study provided the Recovery Program useful information regarding rendezvous sites, duration of site use, and relocation during this critical season. When expanded upon, both the methods and data could be valuable for future management decisions made during the whelping and pup rearing seasons to enhance survival of red wolves. The collection of this data is also an important first step in building future research needs of the Recovery program.

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Table 3.1: Weights of Beechridge pack pups caught at seven weeks of age and 40 weeks of age.

| *Beechridge Pups* | *Weight (kg) at 7 weeks* | *Weight (kg) at 40 weeks* |
| --- | --- | --- |
| **Transmittered** | | |
| 11424M | 3.9 | 23.6 |
| 11427M | 3.6 | 23.6 |
| 11428F | 3.6 | 25.0 |
| 11431M | 3.9 | 31.8 |
| Averages for Transmittered | 3.8 | 26.0 |
| **Untransmittered** | | |
| 11425F | -- | 20.9 |
| 11426M | -- | 28.4 |
| 11429F | -- | 15.9 |
| 11430F | -- | 19.5 |
| Averages for Untransmittered | -- | 21.2 |

Table 3.2: Mean values for estimated distances from pups for the Beechridge pack.

| Data | N | Mean distance to pups | SE | Mean distance to others | SE |
|---|---|---|---|---|---|
| Adults | 199 | 586 | 39.63 | 739 | 35.88 |
| Juveniles | 202 | 661 | 42.53 | 765 | 42.02 |
| Males | 203 | 573 | 33.24 | 693 | 33.65 |
| Females | 198 | 675 | 47.91 | 813 | 43.74 |
| Day | 219 | 622 | 41.28 | 853 | 40.10 |
| Night | 185 | 626 | 40.95 | 633 | 35.48 |
| July | 193 | 593 | 39.82 | 785 | 39.41 |
| August | 156 | 630 | 46.39 | 782 | 43.96 |
| September* | 52 | 717 | 96.06 | 544 | 76.65 |

*Data collection stopped on September 12$^{th}$.

Table 3.3: Mean values for estimated distances of Beechridge pups to each other.

| Data | N | Mean distance to pups | SE | Mean distance to others | SE |
|---|---|---|---|---|---|
| Pups | 408 | 129 | 6.26 | 654 | 19.41 |
| Day | 202 | 147 | 9.53 | 654 | 28.76 |
| Night | 206 | 111 | 7.98 | 653 | 26.29 |
| July | 212 | 71 | 4.13 | 642 | 23.24 |
| August | 143 | 209 | 13.00 | 647 | 32.57 |
| September* | 53 | 140 | 15.64 | 720 | 76.94 |

* Data collection stopped on September 12th.

Table 3.4: ANOVA table for the estimated distance of Beechridge pack members from pups.

| Data | DF | SS | F-Value | P-Value |
|---|---|---|---|---|
| Wolf | 3 | 7481702.20 | 7.711 | <0.0001 |
| Sex | 1 | 1031614.43 | 3.052 | 0.0814 |
| Age | 1 | 560343.46 | 1.652 | 0.1994 |
| Habitat | 3 | 6667654.44 | 6.796 | 0.0002 |
| Part of Day | 1 | 1521.29 | 0.004 | 0.9467 |
| Month | 2 | 631323.99 | 0.929 | 0.9290 |

Table 3.5: ANOVA table for the estimated distance of Beechridge pups from other pups.

| Data | DF | SS | F-Value | P-Value |
|---|---|---|---|---|
| Pup | 3 | 16686.44 | 0.347 | 0.7917 |
| Habitat | 2 | 111493.65 | 1.755 | 0.1371 |
| Part of Day | 1 | 128011.11 | 8.155 | 0.0045 |
| Month | 2 | 1633586.74 | 67.965 | <0.0001 |

Table 3.6: Chi-square table for the estimated attendance of pups by Beechridge pack individuals.

| Data | DF | $\chi^2$ | P-Value |
|---|---|---|---|
| Wolf | 3 | 12.88 | 0.0049 |
| Sex | 1 | 7.47 | 0.0063 |
| Age | 1 | 11.41 | 0.0007 |
| Part of Day | 1 | 9.01 | 0.0027 |
| Month | 2 | 5.01 | 0.0817 |

Figure 3.1: Frequency distribution of distances Beechridge pack members were found from the pups.

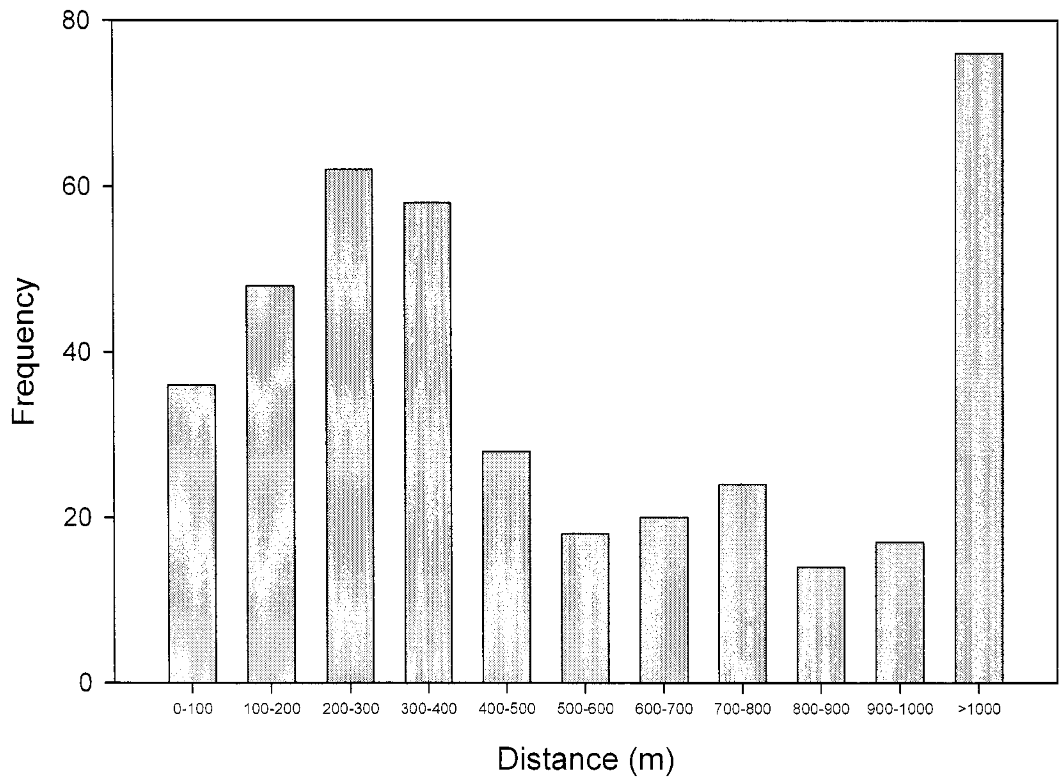


Figure 3.2: Frequency of estimated distances from pups for adults, juveniles, and pups of the Beechridge pack.

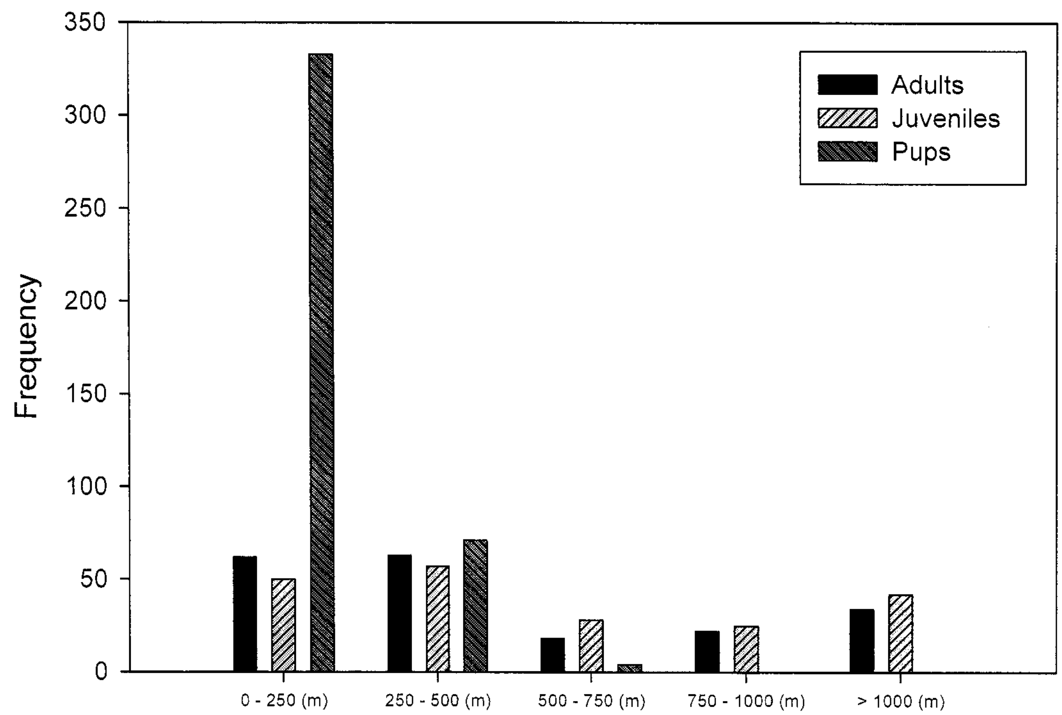


Figure 3.3: Frequency of estimated distances from pups for adult and juvenile males and females of the Beechridge pack.

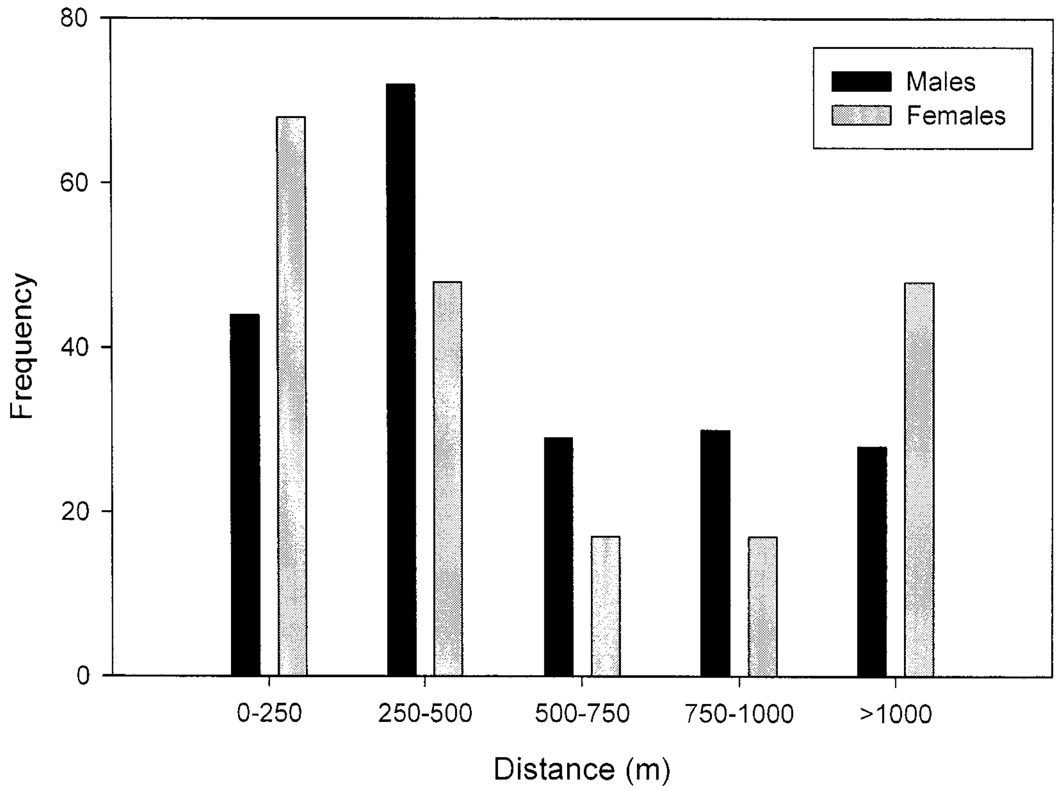


Figure 3.4: Frequency distribution of the locations Beechridge pups were found with other members or alone.

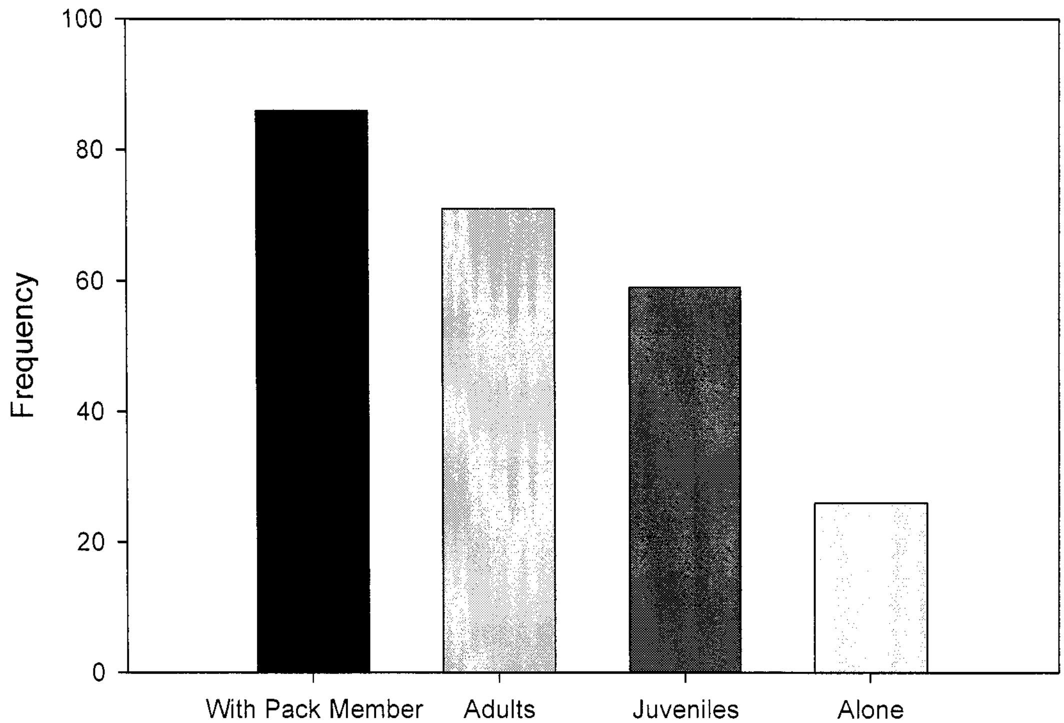


Figure 3.5: Frequency distribution of locations Beechridge pups were found with females, males or both.

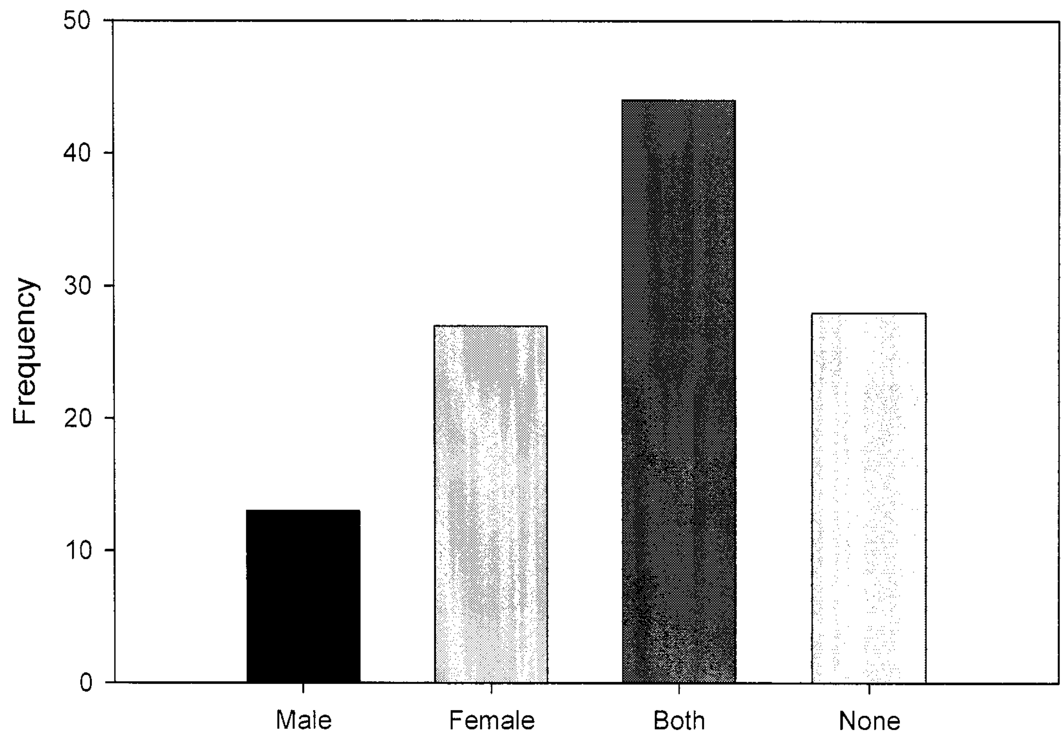
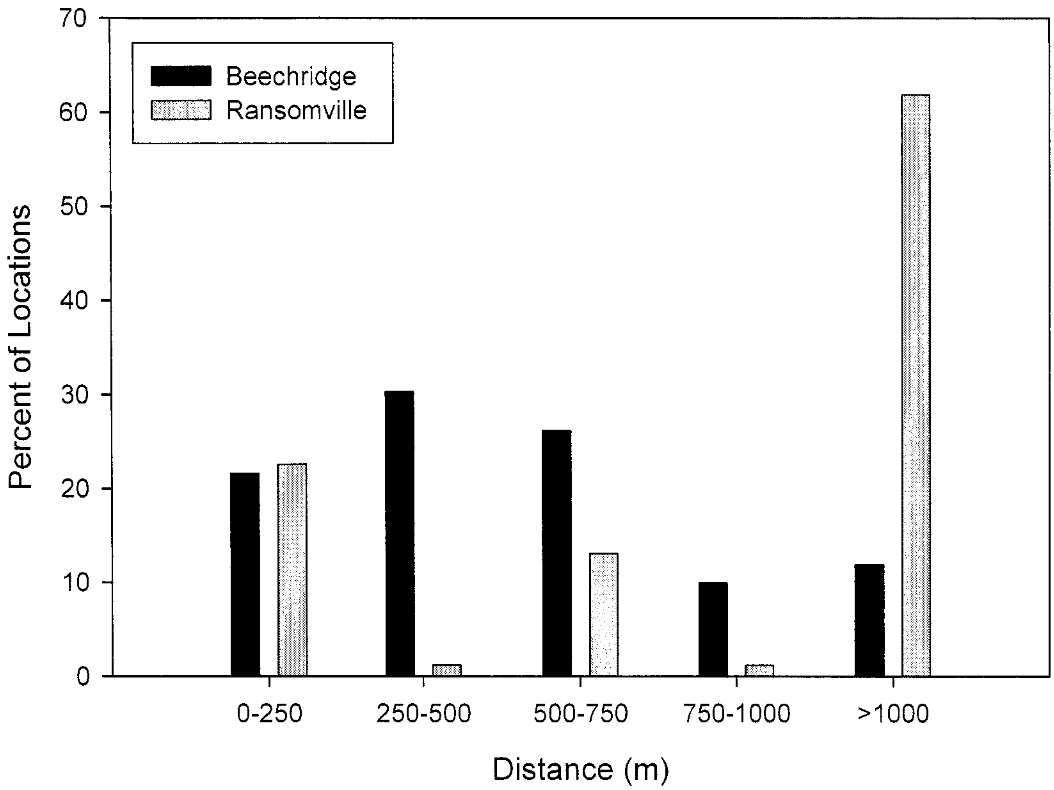
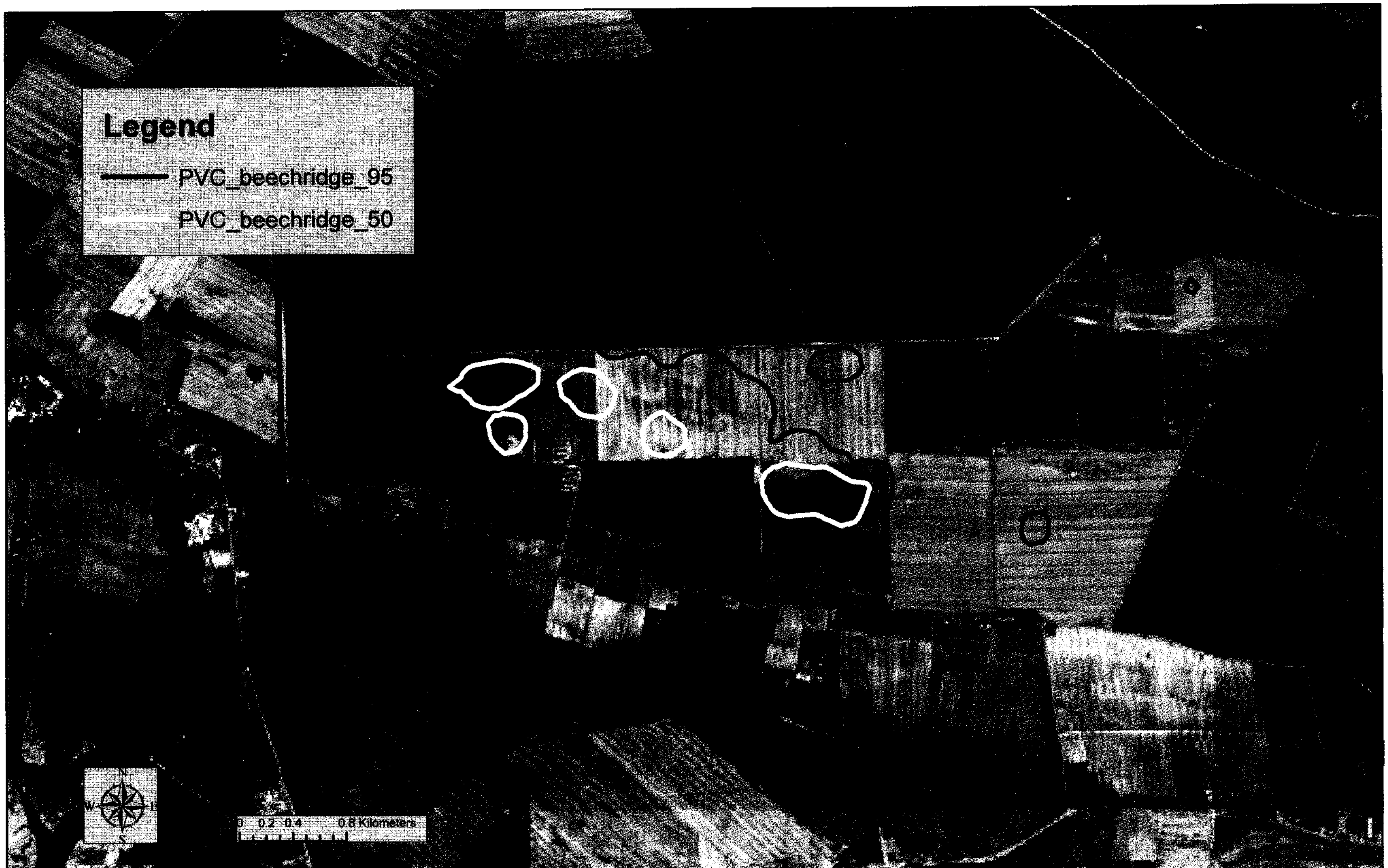


Figure 3.6: Percentage of locations of Beechridge pack members and Ransomville pair found from each other.



# Appendix


Appendix 1. Fixed-Kernel estimation of the Ransomville pair's 95% home range (black) and 50% core (white) contour lines overlaid on color orthophoto imagery.




Appendix 2. Fixed-Kernel estimation of the Beechridge Pack's 95% home range (black) and 50% core (white) contour lines overlaid on color orthophoto imagery.