# *Dispersal Patterns of Male White-tailed Deer in Centre County, PA*

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*Abstract:* Dispersal direction of male white-tailed deer (*Odocoileus virginianus*) has been hypothesized to be influenced by landscape features such as ridges and valleys. We monitored the dispersal distances and directions of 36 yearling males in Centre County during spring dispersal periods 2002-2004 and fall dispersal periods 2002-2003 using radio telemetry. We hypothesized that the dispersal direction of deer would be bimodal and parallel to the ridge lines in the study area ($\square_0$ = 66°, $\square_1$ = 246°). We found no difference in direction between spring and fall dispersal periods, and no difference between years. The mean angles ($\square_1$ = 89, 95% CI = 71-109; $\square_2$ = 269, 95% CI = 251-289) were different from the direction of the ridgelines. Thus, we concluded that yearling male dispersal is directed but not parallel to the ridges and valleys of Centre County. We recommend future research investigate whether habitat features, natural and man-made barriers, and response to human contact influences dispersal direction.

## Introduction

Dispersal among animals is common and is often considered a means to minimize inbreeding (Shield 1987) and serve as a mechanism for establishing new populations or facilitating species range expansion. However, wildlife managers typically ignore dispersal, assume it to be nonexistent, or assume that immigration and emigration are equal (Rosenberry et al. 1999). Mammalian dispersal is typically male biased to avoid inbreeding (Greenwood 1980) and dispersal is most prevalent among yearling bucks in white-tailed deer (*Odocoileus virginianus*, Marchinton and Hirth 1984). Social pressures have been hypothesized to prompt natal dispersal of yearling male white-tailed deer during the breeding season (i.e., August to November) or during the fawning season (i.e., May to June). For example, sexual competition with other males (Kammermeyer and Marchinton 1976) and aggression from a yearling male's mother (Holzenbein and Marchinton 1992a) or related adult females (Ozoga and Verme 1985) has been implicated as potential proximate mechanisms of dispersal. Inbreeding avoidance, as exemplified by maternal antagonism, has been shown to influence dispersal rates of orphan and non-orphan juvenile males, such that orphaned males are less likely to disperse than non-orphans (Holzenbein and Marchinton 1992). For white-tailed deer, natal dispersal by yearling males represents a potentially significant exchange of individuals across areas. Yearling male dispersal can lead to changes in population sizes (Hawkins et al. 1971) and sex ratios (Kammermeyer and Marchinton 1976, Marchinton 1984, Rosenberry et al. 1999).

White-tailed deer typically disperse 8-12 kilometers but movements >200 kilometers have been reported (Kernohan et. al 1994). Some studies have shown that deer movements are directional and associated with watersheds (Sparrowe and Springer 1970). Meanwhile, according to Dusek et al. (1989), dispersal was bimodal on roughly a northeast-southwest axis that conformed to that of the Lower Yellowstone River valley, whereas other studies have shown no relation to dispersal and physiographic features (Verme 1973, Kilgo et al. 1996).

Understanding dispersal patterns is important for effective management of deer (Miller et al. 1995), and dispersal data can help assist in the prediction of movement and spread of diseases. Diseases, such as chronic wasting disease (CWD), have presented problems for many states in the Midwest. Chronic wasting disease is fatal in white-tailed deer, mule deer (*O. hemionus*), and elk (*Cervus elaphus*) and is caused by transmissible protease-resistant prion proteins (Joly et al. 2003). Current epidemiological models suggest that CWD is lethal and presence of the disease can result in complete extirpation of infected populations (Miller et al. 2000). Knowledge of dispersal movements would be helpful when formulating strategies to control or minimize the spread of CWD.

Centre County has long linear ridges and valleys that could potentially influence dispersal direction. The distinct division between the ridges and valleys provide habitat preferred by deer because of the juxtaposition of forested and field vegetative types. According to Hiller (1996), the edge of forests and agricultural fields supply a wide diversity of food, shelter, and habitat components for deer. Centre County is an appropriate site for this study on dispersal direction. The long linear ridges in the county provide a means to examine potential topographic influences on dispersal direction. Our objective was to capture yearling bucks and monitor their dispersal to test whether the topography of Centre County, Pennsylvania, was related to dispersal direction.

## Study Area

This study was conducted in Centre County, Pennsylvania. Centre County (2,870 $km^2$) spans both the Allegheny Plateau and the Ridge and Valley region of Pennsylvania. Our study area in southern Centre County lies within the Ridge and Valley region. Unlike northern Centre County, the southern region is primarily private land, though some public lands exist primarily on the ridges. Ridges are primarily forested with mixed or hardwood tree species and oriented in a northeast (66°) - southwest (246°) direction. The Centre County area represents a landscape with both agricultural and heavily wooded areas. Deer densities range from 21 - 43 deer per square mile of land (Pennsylvania Game Commission 2003). Common tree species on the study area include northern red oak (*Quercus rubra*), white oak (*Quercus alba*), red maple (*Acer rubrum*), white pine (*Pinus strobus*), and yellow poplar (*Liriodendron tulipifera*).

# Methods

## Capture and Data Collection

We captured yearling males 6-9 months of age using drop nets, Clover traps, and rocket nets (Bookhout 1994). Upon capture, deer were masked and sedated (Rosenberry et al. 1999). We tagged each ear with two uniquely numbered ear tags, which were labeled with contact information. Each deer was then fitted with a VHF-transmitter or Global Positioning System (GPS) collar.

Each deer was monitored and located 1-3 times per week using biangulation of signal bearings from >1 known locations. We obtained more signal bearings from additional locations if radio signals were disrupted by radio traffic, electrical interference from power lines, and signal bounce created by the topography of the study area. Aerial telemetry was used to locate deer that dispersed long distances and could not be located from the ground. Location data were entered into LOAS 2.04 and plotted on a map of Centre County.

We defined dispersal as the movement of an individual from its birth home range to the place where it reproduces or would have reproduced if it had survived and found a mate (Nelson 1993). Dispersal movements are long-distance movements without return to previously established home ranges and occur in most white-tailed deer populations (Kernohan et al. 1994). Dispersal occurs during spring and fall; we defined spring dispersal as May to the end of June and fall dispersal as September to November. For bucks that did not disperse, adult home range formation was defined to have begun 1 November.

## Data Analysis

We calculated mean natal and adult locations for each buck. Dispersal distance and direction were the distance and direction from the mean natal locations to the mean adult locations. We consulted several other studies to choose a minimum value of dispersal distance. Nelson (1993) stated that movements <4 km were recorded as 0 dispersal distance. According to Kilgo et al. (1996) and Rosenberry et al. (2001), dispersal was classified as a movement $\geq$2 kilometers from the natal range. Therefore, we classified a buck as a disperser if it moved $\geq$3 km from its natal home range because this criterion was used in other studies.

The Multi Response Permutation Procedure (MRPP; Cade and Richards 2001), using the ARC option for directional data, was used to test for yearly and seasonal differences in the dispersal directions for the sample. We used the V test (Batschelet 1981) (Figures 1, 2a, 2b) to test whether dispersal direction of the yearling bucks was uniform or directed. We define:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n}\cos(2\theta_i)$$

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n}\sin(2\theta_i)$$

$$r = \sqrt{\bar{x}^2 + \bar{y}^2}$$

$$\bar{\theta} = \begin{cases} \arctan\left(\frac{\bar{y}}{\bar{x}}\right) if\ \bar{x} > 0 \\ 2\pi + \arctan\left(\frac{\bar{y}}{\bar{x}}\right) if\ \bar{x} < 0 \\ \pi/2\ if\ \bar{x} = 0\ and\ \bar{y} > 0 \\ 3\pi/2\ if\ \bar{x} = 0\ and\ \bar{y} > 0 \end{cases}$$

where $n$ = number of juvenile males who dispersed greater than 3 km and $\theta$ is the direction the animal dispersed in radians, and

$$V = r \cdot \cos(\bar{\theta} - 2\theta_0),$$

where $\theta_0 = 66 * \pi/180$ is the direction of the ridges. We then used the test statistic U to test for uniformity of direction:

$$U = V \cdot \sqrt{2n}\ .$$

If dispersal were directional based on the V test, we calculated mean dispersal angles and 95% confidence intervals using 999 bootstrapped samples. If 95% CIs overlapped the direction of the ridges ($\theta_0$ = 66°, $\theta_1$ = 246°) we concluded that we had no evidence that dispersal direction was not parallel to the ridges.

## Results

We captured 140 yearling bucks and located them by radio telemetry over 3 years. Of these, 50 were censored because of lack of location data for either natal or adult ranges because of deer mortality or failed transmitters. Fifty-four deer were not included in the analyses either because they did not disperse or apparent dispersal movements were <3 km. The remaining bucks ($n$ = 36) provided dispersal data that matched our inclusion criteria. Dispersal distance ranged from 3.1 km to 21 km and the mean dispersal distance was 7.8 km. We found no difference in dispersal direction between years and seasons (MRPP test, $P > 0.10$). Therefore, we pooled data from all years and seasons. The V test for uniformity of direction was rejected (U = 2.17; $P < 0.05$). The mean angles ($\theta_1$ = 89, 95% CI = 71-109; $\theta_2$ = 269, 95% CI = 251-289) were different from the direction of the ridgelines (Figure 3).

## Discussion

The results indicate that deer dispersal was directed, and dispersal directions were similar to ridges and valleys in Centre County. However, 95% CIs of the dispersal direction did not overlap the exact angles of the ridges and valleys. The ridges and valleys align with a northeast-southwest direction; however, average dispersal direction of bucks was approximately east-west. We have no explanation for the direction of dispersal that we observed.

One possible explanation is the presence of quality habitat. The ridges and valleys in Centre County along with agricultural clearings create edge habitat appropriate for deer. This edge provides a wide diversity of food, shelter, and habitat components (Hiller 1996). Deer prefer areas where two vegetative types such as woods and fields or grasslands and brush come together such as in the ridges and valleys of Centre County. This edge habitat is encountered when moving east or west along the ridges and valleys. As a conceivable result, the male juveniles are dispersing in these directions. However, in one study conducted by Kilgo (1992), influences on animal movements such as food quality, water, and refugia possibly affected the movements of a few individuals in Florida, USA, whereas in another study conducted by Kilgo et al. (1996), food and habitat did not offer satisfactory explanations to why dispersal was in an east-west direction. Food availability becomes a possible factor in influencing dispersal because it differentiates from spring dispersal period to fall dispersal period and can potentially cause the juvenile bucks to disperse across the ridges and valleys. Further research is needed to determine whether habitat quality and food availability affect dispersal direction.

Another factor that can be influencing dispersal is seasonally changing habitat. When cover conditions were optimum, as in summer, deer movements tend to be limited (Sparrowe and Springer 1970). When cover is scarce, deer movements are partly controlled by available heavy cover. According to Sparrowe and Springer (1970), deer often crossed wide expanses of open fields between patches of heavy cover in eastern South Dakota. Juvenile males are possibly dispersing wherever there is heavy cover on the ridges and valleys during the spring dispersal, whereas, during the fall dispersal, essential cover becomes limited. This limitation potentially affects dispersal direction during the fall dispersal period. Many deciduous forests within the study area become bare, whereas patches of evergreen trees are visible on ridges and valleys. These patches of evergreen trees can pose as a corridor for dispersal during the fall dispersal period, assuming these patches are large enough for long distance dispersal. Research must be conducted to test and compare dispersal direction between dispersal periods where habitat is changing seasonally.

Long distance dispersal may also be directed due to barriers. The valleys in Centre County contain farms and residential areas. These areas include human interaction, possible encounters with dogs, and car collisions, which are a major cause of white-tailed deer fatalities. Major highways, together with agricultural and residential areas, may represent barriers to deer dispersal, and juvenile males at the edge of the ridges and valleys may disperse east or west to avoid human contact. Movements in any other direction, including our hypothesized directions, require the deer to cross major highways such as I-80. The presence of cars may possibly induce juvenile males to disperse parallel to major highways. Additional research is needed to test whether roadways pose as a barrier to deer and may cause directional dispersal.

According to Dusek et al. (1989), juvenile male white-tailed deer dispersed along the river bottom of the Lower Yellowstone River. Twenty-seven of 33 dispersing deer did not cross the river itself but had a tendency to remain in the river bottom. Waterways such as rivers and streams can be potential natural barriers. However, in our study area, deer did disperse across the areas where Penns and Bald Eagle Creeks lie, suggesting these smaller streams may not be major factors influencing dispersal direction.

Future research can be conducted to investigate whether other factors influence dispersal direction. Possible factors include habitat features, natural and man-made barriers, and human contact.

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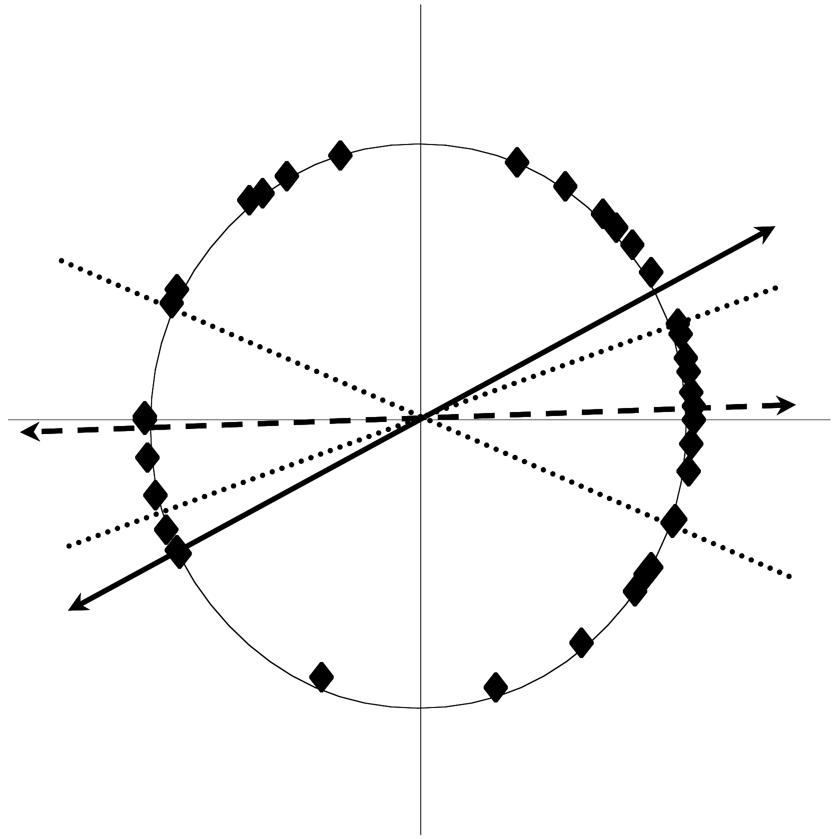

Figure 1. Observed dispersal directions of juvenile male white-tailed deer (n=36) in Centre County, PA, 2002-04. 95% confidence intervals (dotted lines) of mean dispersal directions (dashed line) did not overlap hypothesized mean dispersal directions (solid line), which are parallel to ridges and valleys in the study area.