RED FOX SPATIAL CHARACTERISTICS IN RELATION TO WATERFOWL PREDATION

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Abstract: Radio-equipped red foxes (Vulpes vulpes) on the Cedar Creek area in Minnesota were spatially distributed, with individual families occupying well defined, nonoverlapping, contiguous territories. Territory boundaries often conformed to natural physical boundaries and appeared to be maintained through some nonaggressive behavior mechanism. Individual foxes traveled extensively throughout the family territory each night. Fox territories appeared to range from approximately 1 to 3 square miles in size, dependent largely on population density. Red foxes used a sequence of dens to rear their pups, and the amount and location of food remains at individual dens changed as the pups matured. The denning season was divided into pre-emergence, confined-use, and dispersed-use periods of 4 to 5 weeks each. Remains of adult waterfowl were collected at rearing dens on six townships in three ecologically different regions of eastern North Dakota. Remains of 172 adult dabbling ducks and 16 adult American coots (Fulica americana) were found at 35 dens. No remains from diving ducks were found. The number of adult ducks per den averaged 1.6, 5.9, and 10.2 for paired townships in regions with relatively low, moderate, and high duck populations, respectively. Eighty-four percent of the ducks were females. The species and sex composition of ducks found at dens during early and late sampling periods reflected the nesting chronology of prairie dabbling ducks. Occupied rearing dens were focal points of red fox travel, and the locations of dens may have had considerable influence on predation. Thirty-five of 38 dens found on the six township study areas were on pastured or idle lands. The distribution of rearing dens on the Sand Lake and Arrowwood national wildlife refuges suggested that, on these areas, fox dens were concentrated because of the topography and land-use practices.

Red foxes are abundant throughout much of the prairie waterfowl production areas in the United States and Canada. They prey on waterfowl and their eggs, but few data are available that document the use of these food sources by red foxes.

The purposes of this paper are to discuss certain spatial characteristics of red foxes that relate to their population densities and predator-prey interactions, and to portray and discuss red fox utilization of adult waterfowl during the nesting season. Data included in this paper came primarily from (1) literature on the subject, (2) a study on the ecology and behavior of radio-equipped red foxes on the Cedar Creek Natural History Area in east-central Minnesota, (3) a study of red fox utilization of adult waterfowl on six townships in eastern North Dakota, and (4) observations on locations of red fox dens on Sand Lake National Wildlife Refuge, South Dakota, and Arrowwood National Wildlife Refuge, North Dakota. Only certain aspects of these studies that demonstrate specific characteristics of red foxes in relation to their interactions with waterfowl populations are presented. A more detailed and comprehensive report on the Cedar Creek study is being prepared for publication.

STUDY AREAS

The Cedar Creek study area consisted of 16 square miles centering on the Cedar Creek Natural History Area in Anoka and Isanti counties, Minnesota. This area contains a mixture of deciduous woodlots, cultivated and idle fields, and open and wooded swamps. Several lakes and marshes, a permanent stream, and numerous small farms and well-traveled roads are scattered throughout the area. The heterogeneous makeup of this study area provided a varied environment for the resident fox population.

Six township study areas were selected in three ecologically different prairie regions of eastern North Dakota (Fig. 1). These sites were not intended to represent broad
Wildlife Refuge is in Brown County in northeastern South Dakota. Both refuges, comprised of narrow zones of land bordering impounded lakes and marshes along the James River, are surrounded by cultivated lands.

For the Cedar Creek study I am indebted to D. W. Warner and B. R. Peterson, who were primarily responsible for the author's participation and provided guidance and support throughout the study; W. W. Cochran and V. B. Kuechle provided the necessary electronics assistance; D. B. Siniff contributed much help in the development of computerized data-processing methods; J. E. Forbes was the principal field assistant; and R. L. Himes captured the necessary study animals. This study was generously supported by the Louis W. and Maud Hill Family Foundation of St. Paul, Minnesota; the National Institutes of Health, U. S. Public Health Service Training Grant 5T1 AI 188; and the Bureau of Sport Fisheries and Wildlife, Division of Wildlife Services.

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For help in documenting red fox population densities and their utilization of waterfowl on the six townships in North Dakota, I am grateful to C. M. Pfeifer, who served as both pilot and observer, and to W. K. Pfeifer, who served as an experienced observer on all aerial flights. R. T. Eberhardt and S. H. Allen assisted in collecting and examining food remains found at red fox dens, and R. E. Stewart and H. A. Kantrud provided information on waterfowl composition and population densities in eastern North Dakota.

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paper I am particularly grateful to P. F. Springer and F. B. Lee.

METHODS

The movements of 32 radio-equipped red foxes were followed on the Cedar Creek study area from 1963 through 1965 with the use of portable radio-tracking equipment and the Cedar Creek automatic radio-tracking system (Cochran et al. 1965). Most of these foxes were captured in steel traps with attached tranquilizer tabs (Balser 1965). The automatic tracking equipment enabled simultaneous, semicontinuous recording of the location of most study animals. Data recorded on photographic film by the tracking system were extracted manually and placed on punch cards for computer processing. Because of the large amount of data, analysis was based on a sampling of fox movements at 10-minute intervals, whenever possible. Signal losses due to equipment limitations occurred periodically, with resultant minor gaps in the data, but these losses did not prevent me from obtaining an accurate record of fox movements.

Systematic aerial searches to locate red foxes and active rearing dens were conducted over each of the six township study areas during April 10–12, May 20–24, and June 16–18, 1969. Individual townships were flown at elevations of approximately 150 to 250 feet during periods of favorable light and weather conditions on transects spaced 0.25 mile apart. Dense habitats were circled for more complete checks. The same pilot and two observers participated in all flights. After each flight, landowners were contacted, and rearing dens were visited and partially or completely excavated. All food remains were collected for future identification. When pups were captured they were ear-tagged and released back into the dens.

Red fox dens were located by ground observations on Sand Lake Refuge during May 1968 and on Arrowwood Refuge during May and June 1969.

RESULTS

Fox Spatial Occupancy and the Social Group

An understanding of red fox spatial occupancy requires consideration of the social structure of the species. The red fox family, which forms the basic social group, typically consists of an adult male and female, and their pups from whelping to dispersal. Seton (1929) referred frequently to the fox family. Scott (1943:444–446) emphasized the importance of the fox family unit and recognized the tendency of individual families to occupy relatively exclusive ranges on the Moingona area in Iowa. Ables (1969) used radiotelemetry and documented the movements of two spatially separated but adjacent groups of red foxes on the 1,200-acre University of Wisconsin Arboretum, an area of mixed prairie, forest, and marshes, surrounded in part by a residential area.

Scott (1943:441) suggested that if “positive reaction to a particular place and familiarity with the environment are manifestations of territory then territorialism is characteristic of the red fox.” Territorialism as used in this paper incorporates Scott’s definition but also denotes exclusive occupation of specific areas by discrete families.

Unpublished results from the Cedar Creek study established that individual red fox social groups (families) mutually occupied well-defined, nonoverlapping, contiguous territories. Territorial integrity appeared to be maintained through some nonaggressive behavior mechanism. Boundaries of territories were not patrolled, yet there appeared to be an acute awareness of the presence and a mutual avoidance between family members holding adjacent territories.
Fig. 2. Home ranges of three red foxes in east-central Minnesota during May 6–June 3, 1964. The lines between fox locations connect consecutive points in travel separated by no more than a 1-hour difference in time.

Territorial boundaries were well established and often conformed to natural physical boundaries such as roads, streams, and lake shores. Wet habitats such as marshes and swamps were avoided to varying degrees during the ice-free seasons but were used during the winter. All other habitats were occupied by foxes during all seasons. Except for the seasonal avoidance of wet habitats near territory boundaries, contiguous red fox territories encompassed nearly all land area.

Individual foxes generally traveled throughout much of the family territory each night. The home range of any adult family member during a 2-week period portrayed the entire family territory. Thus, individual home ranges and family territories were similar in their spatial attributes.

The territories of three fox families on the Cedar Creek area are shown in Fig. 2 by the home ranges of three adult females during May 6–June 3, 1964. The indicated areas of overlap between females 32 and 35 and females 31 and 35 were caused by minor changes in boundaries of home ranges during the study period, errors in locations of foxes due to limitations of the telemetry system and inaccuracies in recording data (Heezen and Tester 1967), and the method used to delineate the boundaries of the home range. At any specific time there was little overlap of the home ranges of these three females. The unoccupied area between females 31 and 32 was the result of a seasonal avoidance of swampy areas along Cedar Creek by female 32.

Females 31 and 32 whelped and were caring for pups, whereas female 35 was without pups. An adult male resided in each territory. An additional adult female (without pups) lived in the territory with female 32. Thus, three different types of social groups are represented in these data.

The inclusion of at least two adult females in a social group was also observed by Ables (1969), who documented the attachment of two female littermates to the natal area for over a year. Sheldon (1950) suggested the possibility of polygamy in red foxes and presented several instances of communal denning by two litters and one instance where a barren female was caught at an active rearing den. Murie (1961:152–154) reported observing one or more supplemental adults at three dens in Alaska. Three supplemental adult females were seen at one of Murie's dens, and the supplemental adult at another was a male.

Certain red fox spatial characteristics of relevance to this paper were evident from the findings at Cedar Creek and in the literature. Red foxes were highly territorial, and their territories were occupied by all members of the family. Territorial boundaries often conformed to natural physical boundaries, territories often encompassed
areas avoided by foxes in their daily movements, and contiguous red fox territories sometimes occupied nearly all land area.

**Territory Size and Population Densities**

Few detailed descriptions of the size of red fox home ranges are found in the literature. Seton (1929:475) suggested that individual red foxes occupied areas not more than 5 miles in diameter but did not ordinarily range that far. Murie (1936:43) found a pair of red foxes occupying 1,200 acres of the George Reserve in Michigan, plus an undetermined area outside the Reserve. Scott (1943:441) concluded that on the Moingona area in Iowa, "an arc drawn on a one-mile radius would ordinarily circumscribe the movements of the resident individual, pair or family" of red foxes. The *daily range* of Michigan red foxes, determined by following their trails in the snow, was calculated as 1.4 square miles in southern Michigan (Arnold and Schofield 1956) and 2.8 square miles in northern Michigan (Schofield 1960). Storm (1965) found home ranges of 910 and 1,040 acres for two adult male red foxes in northern Illinois. Ables (1969) found the range of an adult male living in a *typical* Wisconsin farming area to be 1,460 acres, but the largest *range* of seven red foxes residing on the confined Wisconsin Arboretum was 400 acres. He suggested that the *richness* of the habitat, in terms of food abundance and availability, was a possible explanation for the small ranges. The Arboretum, however, may have represented an *island* of habitat in a suburban environment that confined the movements of the resident foxes.

The home range sizes for the Cedar Creek foxes shown in Fig. 2 were 2.5, 2.3, and 3.3 square miles for foxes 31, 32, and 35, respectively. The home range of female 35, however, nearly doubled in size between mid-April and mid-May 1964. The area to the west of the western boundary of female 35 was part of the territory of an adjacent family prior to late April 1964. On April 28 a radio-equipped adult male and six pups from this adjacent family were killed. After these deaths, female 35 and her mate rapidly expanded their territory to include part of the area previously occupied by this family. This major adjustment in the territory boundaries suggested that the mother of the six pups had either left the area or was dead.

As previously discussed, the size of the home range of individual red foxes was similar to the size of the territory of the family. Thus, these findings and the home range data previously cited suggested that red fox families tended to occupy territories approximately 1 to 3 square miles in size.

Low red fox population densities with numerous uninhabited areas developed in eastern North Dakota during the winter of 1968–69. Spring population densities on the six township study areas ranged from approximately two to seven families on each township. However, these families appeared to occupy distinct areas despite the low population densities. Red foxes have been abundant in these counties since the early 1940’s and were estimated at 0.8 to 1.4 adult foxes per square mile during the spring of 1944 (North Dakota Game and Fish Dept. 1949). Their decline in 1968–69 occurred during a severe winter when snow cover was optimum for ground and aerial hunting and red fox fur prices were high, ranging up to $13.50 each for unskinned foxes (S. H. Allen, personal communication).

The findings of this and other studies suggested that red foxes have an innate minimum and maximum spatial requirement that was manifested in their territoriality. Within these limits, territory size was a reflection of population density, which
in turn was dependent on overall environmental conditions. As densities of red fox populations diminished, the size of territory of the remaining animals increased. Only when population densities fell below the level at which maximum territory size occurred did uninhabited areas appear in suitable habitat.

Den Ecology

Food remains that accumulated at red fox rearing dens have been used to determine the minimal numbers and the species and sex composition of certain prey used by adult foxes in feeding their pups. Several authors have shown that food remains at dens do not accurately represent the diet of pup foxes, because desirable small items may be totally consumed (Errington 1937, Scott 1947, North Dakota Game and Fish Dept. 1949, Drieslien 1967). The observed incidence of downy ducklings at dens has little meaning, because ducklings are easily consumed. Generally, however, pup foxes leave at least some feathers of adult waterfowl brought to the dens.

Whelping usually occurs during late March or April in eastern North Dakota (North Dakota Game and Fish Dept. 1949), and for 10–15 weeks the pups are confined in or near a sequence of several rearing dens. Scott (1943: 444–446, 1947: 438) and Scott and Klimstra (1955: 13–15) found that individual litters used from three to seven different rearing dens.

Physical and behavioral characteristics of fox pups changed rapidly during the denning season. The denning season was divided into three periods: (1) from whelping to emergence of the pups from the underground burrows (pre-emergence), (2) when all pup activity was confined to the immediate den vicinity (confined-use), and (3) when pup activity was more widely dispersed in the den area and several dens were often used simultaneously (dispersed use). During each of these periods, one or more dens might be used by individual litters.

The three periods of den use lasted approximately 4 to 5 weeks each and were characterized by differences in pup feeding behavior. Pups were nursed during much of the pre-emergence period, and few food remains were present at dens. During the confined-use period, pups consumed whole food items, but the remains were often located underground, and complete excavation of the den was necessary for their retrieval. Most food remains occurred on the surface during the dispersed-use period, but the remains of many waterfowl brought to these dens may have been missed, because they were often almost totally consumed by the pups and the remains scattered over large areas.

Incidence and Abundance of Waterfowl at Rearing Dens

Aerial and ground observations showed that a minimum of 25 red fox families inhabited the six township study areas. The total number of dens noted during each of the three aerial survey periods, and afterwards confirmed as being active or used by the foxes earlier in the season, were 3, 12, and 21, respectively. Two additional dens were located by ground observers. Other studies previously cited showed that red foxes used from three to seven different rearing dens. The township families appeared to follow this same pattern of multiple den use. Thus, the 38 dens visited on the townships were only part of the total number of dens used by the 25 families known to occupy these areas. The total number of adult waterfowl found at the township dens is presented in Table 1. The three dens located during the first aerial survey period were not included since they
were visited during the period of pre-emergence, when few or no food remains were found at dens.

The total number of adult waterfowl utilized by all the families under study on the six townships was unknown. These data represented only a partial count because (1) the identification methods provided minimal counts on the number of waterfowl represented in retrieved remains, (2) many rearing dens used by the families were doubtless not found or were not completely excavated, (3) food remains at the dens represented only food items brought to the dens and did not include food that was consumed or cached elsewhere by the adults, and (4) the denning season terminated prior to the end of the waterfowl nesting season.

Data gathered between May 20 and June 17, 1969, in a study by R. E. Stewart and H. A. Kantrud (personal communication), indicated dabbling duck densities of approximately 32 and 69 pairs per square mile for larger areas of the Drift Prairie and Coteau du Missouri, which included the Barnes County and Stutsman County townships, respectively. Applicable density data for waterfowl were not available for the Kidder County townships on the Outwash Plain. Stewart and Kantrud also found that dabbling ducks represented 95, 83, and 91 percent of the total duck population in the three regions encompassing the Barnes, Stutsman, and Kidder county townships, respectively.

The average number of ducks per den for the Barnes and Stutsman county townships (Table 1) was approximately proportionate to the corresponding duck population densities. The average number of ducks per den (4.9) for the combined data from all six townships was similar to previous findings in 1943–47, when 5.0 ducks per den were identified at 62 dens in eastern North Dakota (North Dakota Game and Fish Dept. 1949).

Differences in red fox utilization of waterfowl between the Barnes and Stutsman county townships with high waterfowl densities and the Kidder County townships with relatively low waterfowl densities were also reflected in the total number of dens with duck remains and the maximum number of ducks at individual dens. Duck remains were found at 18 of 19 dens on the four high-density townships during the confined-use and dispersed-use denning periods and

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**Table 1.** Numbers of adult waterfowl as determined from remains at red fox rearing dens in eastern North Dakota.

<table>
<thead>
<tr>
<th>Den Site</th>
<th>Number of Active Dens</th>
<th>Number of Families</th>
<th>Total Coots</th>
<th>Coots per Den</th>
<th>Total Ducks</th>
<th>Ducks per Den</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnes County</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Township 1</td>
<td>7</td>
<td>3</td>
<td>7</td>
<td>1.0</td>
<td>51</td>
<td>7.3</td>
</tr>
<tr>
<td>Township 2</td>
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<td>3</td>
<td>2</td>
<td>0.5</td>
<td>14</td>
<td>3.5</td>
</tr>
<tr>
<td>Subtotal</td>
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<td>6</td>
<td>9</td>
<td>0.8</td>
<td>65</td>
<td>5.9</td>
</tr>
<tr>
<td>Stutsman County</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Township 3</td>
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<td>4</td>
<td>3</td>
<td>0.5</td>
<td>75</td>
<td>12.5</td>
</tr>
<tr>
<td>Township 4</td>
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<td>2</td>
<td>1</td>
<td>0.5</td>
<td>7</td>
<td>3.5</td>
</tr>
<tr>
<td>Subtotal</td>
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<td>6</td>
<td>4</td>
<td>0.5</td>
<td>82</td>
<td>10.2</td>
</tr>
<tr>
<td>Kidder County</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Township 5</td>
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<td>6</td>
<td>2</td>
<td>0.2</td>
<td>13</td>
<td>1.4</td>
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<td>Township 6</td>
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<td>6</td>
<td>1</td>
<td>0.1</td>
<td>12</td>
<td>1.7</td>
</tr>
<tr>
<td>Subtotal</td>
<td>16</td>
<td>12</td>
<td>3</td>
<td>0.2</td>
<td>25</td>
<td>1.6</td>
</tr>
<tr>
<td>Total or average</td>
<td>35</td>
<td>24</td>
<td>16</td>
<td>0.5</td>
<td>172</td>
<td>4.9</td>
</tr>
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</table>
at only 9 of 16 dens on the two low-density townships. The maximum number of ducks found at a single den on the low-density townships was six. Eight dens on the high-density areas contained remains of 8 to 33 ducks.

Successive dens used by six litters on the high-waterfowl-density townships showed accumulated totals of 1, 12, 18, 19, 24, and 27 ducks for each litter. In no instance, however, were visits made to all of the dens used by a litter. Strangely enough, the family for which only one duck was found lived adjacent to a large marsh with an abundance of waterfowl. Although the foxes appeared to use ducks in proportion to their abundance, no diving ducks were found in the food remains at dens. Diving ducks occurred in all areas, and their non-use by foxes is ascribed to their almost totally aquatic nesting and feeding habits, which made them unavailable to foxes. The relatively high vulnerability of dabbling ducks is discussed in the following section.

American coots represented 12, 5, and 11 percent of the total waterfowl remains at dens in the Barnes, Stutsman, and Kidder county townships, respectively (Table 1). Stewart and Kantrud (personal communication) found that coots represented 6, 27, and 4 percent of the total waterfowl in the regions encompassing these same townships, respectively. The abundance of coots at dens was lowest in the Stutsman County townships, where their actual number and their population composition were apparently highest (Table 1). These results appear inconsistent with the nonuse of diving ducks by foxes, since coots also were almost totally aquatic. Coots, however, unlike diving ducks, were frequently observed walking on the shores of many marshes, where they may have been vulnerable to predation by foxes.

Red foxes utilized a variety of prey species (Errington 1937, Scott 1943, 1947, Scott and Klimstra 1955) and thus were not dependent on waterfowl for their survival. Their utilization of waterfowl was dependent not only on the abundance of vulnerable waterfowl but on the abundance of other vulnerable prey and the predatory behavior of individual foxes. In Barnes and Stutsman counties, waterfowl were undoubtedly the most abundant, large, wild prey species. Meadow mouse (Microtus pennsylvanicus) populations were abnormally high in the spring of 1969, and they were heavily used by the foxes in all six townships. They may have buffered red fox utilization of waterfowl.

**Species and Sex Composition of Dabbling Ducks at Rearing Dens**

The species and sex composition of adult ducks found at the township dens are given in Table 2. The sex ratios of ducks on the townships were unknown, but Bellrose et al. (1961:405–408) determined that males usually predominated among adults in most duck species. It was evident from these data that red fox utilization of adult waterfowl during the nesting season was directed toward female dabbling ducks. The fact that females made up 84 percent of all ducks that were identified as to sex, and that females never comprised less than 75 percent of any single species, clearly indicated selective predation on females.

The physical condition and cause of death of the waterfowl utilized by the township foxes could not be determined. No non-predator mortality, however, such as road-kills was known to occur in sufficient magnitude to account for the number of ducks found at the rearing dens. Agricultural practices, particularly haying, were known to inflict losses on nesting hens, but haying was just beginning in mid-June when the last den surveys were being made. There
was also little evidence of remains from waterfowl utilized by other animals.

Sowls (1955:83, 86–87), comparing the nesting chronology of prairie dabbling ducks, showed that mallards (Anas platyrhynchos) and pintails (Anas acuta) were early nesters, blue-winged teal (Anas discors) and shovelers (Spatula clypeata) were mid- to late-season nesters, and gadwalls (Anas strepera) were late-season nesters. This trend in nest chronology was reflected in the relative species composition of ducks found at the township dens during the sampling periods of May 26–June 4 and June 16–July 9 (Table 2). These differences in species composition were minimized, since many of the dens visited during the late sampling period undoubtedly contained remains from earlier periods.

The high incidence of female dabbling ducks and their change in species composition in accordance with their nesting chronology suggested that most of the waterfowl found at the rearing dens represented selective predation by red foxes on nesting hens.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of Ducks (May 26–June 4)</th>
<th>Species Composition (percent)</th>
<th>Number of Ducks (June 16–July 9)</th>
<th>Species Composition (percent)</th>
<th>Number of Sex-Determined Ducks</th>
<th>Female Ducks (percent)</th>
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</thead>
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<tr>
<td>Blue-winged teal</td>
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<td>26</td>
<td>27</td>
<td>32</td>
<td>39</td>
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<tr>
<td>Pintail</td>
<td>28</td>
<td>38</td>
<td>18</td>
<td>37</td>
<td>21</td>
<td>43</td>
</tr>
<tr>
<td>Shoveler</td>
<td>10</td>
<td>13</td>
<td>13</td>
<td>15</td>
<td>11</td>
<td>100</td>
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<tr>
<td>Mallard</td>
<td>9</td>
<td>12</td>
<td>9</td>
<td>11</td>
<td>16</td>
<td>87</td>
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<tr>
<td>Gadwall</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>14</td>
<td>13</td>
<td>78</td>
</tr>
<tr>
<td>Green-winged teal (Anas carolinensis)</td>
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<td>3</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>75</td>
</tr>
<tr>
<td>American widgeon (Mareca americana)</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>3</td>
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<td>100</td>
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<td>Total or average</td>
<td>74</td>
<td>100</td>
<td>85</td>
<td>100</td>
<td>129</td>
<td>84</td>
</tr>
</tbody>
</table>

Table 2. Species and sex composition of adult ducks at red fox rearing dens in six townships in eastern North Dakota.

Den Location in Relation to Waterfowl Predation

Individual red fox movement was distributed throughout the family territory, but certain behavioral and life history events resulted in specific areas becoming focal points of activity. Foremost among these areas were the active rearing dens. The concentration of movement around rearing dens is illustrated in Fig. 2 by the movement patterns of foxes 31 and 32 on the Cedar Creek area.

Since occupied rearing dens were focal points of red fox travel, the probability of foxes encountering nesting waterfowl near the dens would seem greater than in most areas within the territory. Thus, two areas of similar habitat and similar waterfowl densities in the same fox territory might experience different predation rates, depending on their proximity to the rearing den. This factor became increasingly important during the late stages of the denning season when pup movement was distributed throughout the den area.

Natal den sites may be located anywhere within the red fox territory, but successively used dens were often in the natal area. Red fox dens frequently had a history of previous use, and the site selection appeared unrelated to prey abundance. The locations of the 38 active rearing dens on the six townships were 35 on pasture and idle lands and 3 on cropland. The high use of pastured and idle lands for denning occurred even on the Barnes County townships that were almost completely cultivated.

The distribution of occupied rearing dens
nesting waterfowl than would have occurred if the dens had been located outside the refuge boundaries.

DISCUSSION

Red fox–waterfowl interactions in the prairie wetland region result from the annual influx of migratory waterfowl into areas already occupied by spatially distributed red fox family groups. Thus, unlike many predator–prey relationships, an annual cycle of renewed encounters occurs between foxes and waterfowl. Although red foxes (a terrestrial species) and waterfowl (an aquatic group) occupy different environmental niches during much of the nesting season, dabbling ducks utilize terrestrial habitat for egg-laying and incubation. During this period, nesting hens appear quite vulnerable to predation by foxes and, as shown in Table 1, are used for food.

Red fox predation on waterfowl is related in part to fox population densities. The territorial characteristics of the red fox family group result in complete occupancy of nearly all land areas in the prairie wetland region during periods of moderate to high population densities and the occurrence of uninhabited areas during periods of low densities. However, even during periods of high fox population densities, individual waterfowl engaged in egg-laying and incubation may be exposed to predation by only a single family of foxes. Areas of good habitat that concentrate nesting waterfowl may also be utilized by only the red fox family occupying that area as part of its territory.

During periods of low red fox population densities, predation on individual sites is highly variable, depending upon whether the sites are located inside or outside of territories occupied by foxes. Within territories occupied by foxes, predation may be of similar intensity to that occurring
during periods of moderate fox population densities, whereas outside the territory, no predation from foxes ordinarily occurs unless it is from transient or displaced individuals. Thus, as was observed on the township study areas, although predation by individual red fox families appears substantial, the impact on the total township waterfowl populations was relatively minor because much of the area was unoccupied by foxes.

Red fox predation on waterfowl occurs as the result of encounters between family members and vulnerable waterfowl. Red fox movement within the territory serves two fundamental needs: to maintain the territory and to simultaneously fulfill the necessities of life. Thus, all movement by foxes must not be interpreted as representing or being motivated by hunting behavior. Red foxes travel in and occupy areas not normally used for hunting, and predation may occur in these areas as a result of a circumstantial encounter with vulnerable prey.

CONCLUSIONS

In considering the impact of red foxes on nesting waterfowl, a careful distinction must be made between waterfowl survival and waterfowl abundance. Waterfowl have built-in mechanisms that favor survival in areas of suitable habitat. Thus, renesting by waterfowl compensates in part for egg losses; homing and pioneering are factors in repopulation of depleted areas; and large clutch sizes provide an annual population increment to compensate for various mortality factors.

Red fox population densities appear regulated by inherent species characteristics and overall environmental conditions. Areas with little or no use are often included in fox territories, and uninhabited areas develop between territories during periods of low population densities. Hunting characteristics of individual foxes and the abundance and availability of other prey species possibly are reflected in variable predation rates on nesting waterfowl. These characteristics favor survival of waterfowl in areas occupied by red foxes.

A high priority objective of most waterfowl management programs is to maintain or increase waterfowl populations for recreational use. The loss of adult hen dabbling ducks to foxes affects the annual waterfowl production potential of an area because it occurs at that time of the year when waterfowl populations are at their lowest levels and losses are largely noncompensatory. Furthermore, red fox predation is not restricted to adult waterfowl but also occurs on waterfowl eggs and ducklings. The significance of these losses in terms of waterfowl abundance and the harvestable surplus is unknown but may prove to be substantial in some areas.

Red foxes have considerable economic values and sporting qualities that rank them high as fur and game species. Reduction in fox population densities as a means to alleviate predation has biological, economic, and moral implications. In any attempts to reduce population densities, consideration must be given to the social and spatial characteristics of the species that under normal fox population densities result in the rapid inclusion of uninhabited areas into existing territories. Certainly much more information is needed to understand fox-waterfowl relationships before any measures are employed to prevent red fox predation on waterfowl.

LITERATURE CITED


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