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RESPONSE OF WINTERING BUTEOS TO PLAGUE EPIZOOTICS IN PRAIRIE DOGS

David B. Seery[1] and Daniel J. Matiatos[1]

Abstract.—Several species of raptors winter at Rocky Mountain Arsenal National Wildlife Refuge (Refuge) including the Bald Eagle (*Haliaeetus leucocephalus*), Ferruginous Hawk (*Buteo regalis*), Red-tailed Hawk (*Buteo jamaicensis*), and Rough-legged Hawk (*Buteo lagopus*). Raptors were monitored each winter from 1988–89 to 1996–97 using a standardized road survey. Black-tailed prairie dogs (*Cynomys ludovicianus*) form a major component of the prey base for wintering raptors on the Refuge, with 1850 ha of active prairie dog towns mapped in 1988. Prairie dog town areas and population data were determined by mapping active towns and conducting visual counts on study plots to determine population density on an annual basis from 1988 to 1996. Large-scale plague epizootics were documented on the Refuge in 1988–89 and 1994–95, reducing prairie dog towns by 95% and 99%, respectively. A significant relationship was found in the numeric response of Ferruginous Hawks to changes in prairie dog town area ($r^2 = 0.96$, $P < 0.001$) and minimum estimated population ($r^2 = 0.97$, $P < 0.001$), but not to estimated prairie dog density ($r^2 = 0.07$, $P = 0.486$). This contrasted sharply with the responses to prairie dog town area found for Red-tailed ($r^2 = 0.11$, $P = 0.377$) and Rough-legged Hawks ($r^2 = 0.04$, $P = 0.612$).

Key words: buteos, raptors, prairie dogs, plague, predator/prey response.

Several species of raptors winter on the Rocky Mountain Arsenal National Wildlife Refuge (Refuge), including the Bald Eagle (*Haliaeetus leucocephalus*), Ferruginous Hawk (*Buteo regalis*), Red-tailed Hawk (*Buteo jamaicensis*), and Rough-legged Hawk (*Buteo lagopus*). More than 70 Bald Eagles have been observed simultaneously using a communal roost site on the Refuge, and large numbers of buteos were counted on road transects during 1988 (U.S. Fish and Wildlife Service 1989). This makes the Refuge an opportune area for evaluating the relationship between wintering buteos and prairie dogs. Black-tailed prairie dogs (*Cynomys ludovicianus*) create, through their burrowing and grazing activities, a dynamic component of the short- and mid-grass prairies, the "prairie dog ecosystem." This ecosystem provides habitat for a wide variety of wildlife species, from black-footed ferrets (*Mustela nigripes*) and Burrowing Owls (*Athene cunicularia*) to swift fox (*Vulpes velox*) and Mountain Plovers (*Charadrius montanus*). Prairie dogs may therefore be considered a *keystone species* to the shortgrass prairie (Miller et al. 1994). Clark et al. (1989) found more than 100 vertebrate species associated with prairie dog colonies, and Kotliar et al. (1997) found at least 10 species to be dependent on prairie dogs for their survival. Prairie dogs form a major component of the prairie ecosystem on the Refuge, occupying 1850 of 6900 ha (27%) in October 1988 (Stollar et al. 1992).

Plague (*Yersinia pestis* infection) epizootics have periodically affected prairie dog towns on the Refuge from 1988 to 1995 (Ebasco Services, Inc. 1989, U.S. Fish and Wildlife Service 1996). To maintain crucial habitat for wintering raptors, especially the Bald Eagle, the U.S. Fish and Wildlife Service (Service) began working to reestablish prairie dogs to their former levels. The focal point of this effort was prairie dog relocations into areas previously occupied, based largely on the1988 (pre-plague) distribution (Ebasco Services, Inc. 1989). From 1989 to 1993 the Service relocated 5800 prairie dogs to the Refuge from off-Refuge sources (U.S. Fish and Wildlife Service 1994). A monitoring program to gauge effectiveness of the relocation program was initiated and included mapping active prairie dog towns and determining prairie dog abundance.

Other researchers have documented changes in populations of breeding (Woffinden and Murphy 1977, Smith et al. 1981) and migratory

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(Cully 1991) raptors during prey declines. Data presented herein examine fluctuations in prairie dogs caused by plague epizootics and concurrent changes in the number of wintering raptors.

Data we present were collected to establish baseline population levels for a wide variety of wildlife species found on the Refuge prior to and during cleanup operations. Therefore, we did not establish a priori a rigorous study design specifically for analyzing prairie dog and raptor population data.

DESCRIPTION OF STUDY AREA

The Refuge, located approximately 16 km northeast of downtown Denver, was established in 1942 by the U.S. Army to manufacture chemical and incendiary weapons. After World War II private companies leased the arsenal's industrial sites for the manufacture of pesticides and herbicides. Designated a Superfund site in 1986, the arsenal is currently undergoing environmental remediation. Congress passed legislation in 1992 that establishes the arsenal as a national wildlife refuge upon completion of environmental cleanup. The Refuge Act also states the arsenal will be managed "as if it were a national wildlife refuge" during the cleanup. Data collected and analyzed here are part of a larger-scale effort to characterize populations of wildlife at the Refuge. The Refuge currently covers over 6900 ha in a mosaic of habitat types including wetland, riparian, and various types and successional stages of grasslands.

METHODS

Raptor Surveys

Road surveys were used to monitor raptor abundance and distribution on the study area and to provide an index of raptor habitat use and availability. Road censusing is a cost-efficient method of surveying widely distributed raptors. This method has been used extensively by a number of researchers to monitor raptor population trends (Johnson and Enderson 1972, Bauer 1982) and habitat/perch use (Marion and Ryder 1975, Fischer et al. 1984).

We surveyed raptors weekly or biweekly from November 1988 through March 1997. Surveys were conducted along a 38.6-km route, 2 h after sunrise on calm days with no precipitation, by a single observer from an automobile traveling at 24–32 km h^{-1}. Only birds observed with an unaided eye were recorded. However, if birds were not readily identifiable to species, the vehicle was stopped and the observer used binoculars or a spotting scope to make an identification. Species, age class when possible, activity, perching substrate, segment (km) of transect, and a specific location were recorded for each raptor observed.

Simple linear regression was used to analyze prairie dog and raptor data, with significance for the regression model determined at $P < 0.05$.

Prairie Dog Distribution

Prairie dog distribution was determined using aerial photo interpretation and field verification in all surveys conducted from 1988 to 1993 (Ebasco Services Inc. 1989, U.S. Fish and Wildlife Service 1994). We used frosted mylar placed over black-and-white section photographs as a field reference guide. Boundaries of prairie dog towns were then marked with a pencil in the field. Boundaries of black-tailed prairie dog towns are generally easy to identify by the marked change in vegetation height. Mapping was usually conducted in the spring after emergence of prairie dog litters. Upon completion of field mapping, we determined the area of each town using a Radian's Contour Plotting System-1 (CPS-1) for the 1988–1990 surveys and an electronic planimeter for the 1991–1993 surveys.

Prairie dog town distribution was mapped in 1994–1996 using a Global Positioning System (GPS) and software (Pathfinder™) from Trimble Navigation Limited (Sunnyvale, CA). We collected data in the field using a TDC1 GPS datalogger. GPS positions were collected by walking the perimeters of active prairie dog towns and recording positions at 10- to 15-sec intervals. GPS data files collected and stored in the rover unit were then downloaded to a computer with Pathfinder™ software for subsequent differential analysis. Differential correction (to increase accuracy to 2–5 ms) was completed using community base station files downloaded from the U.S. Forest Service in Fort Collins, Colorado. We then read area features (i.e., prairie dogs towns) and determined the size of each area using Pathfinder™ software. Final maps were developed with ArcView™ software (Esri Inc., Redlands, CA).

Prairie Dog Abundance

Visual counts have been used to estimate populations of white-tailed prairie dogs (*Cynomys leucurus*) and Richardson's ground squirrels (*Spermophilus richardsonii*) and have been shown to correlate well with estimates obtained from mark-recapture data from the same sites (Fagerstone 1983, Fagerstone and Biggins 1986, Menkins et al. 1990). We chose visual counts, developed to evaluate black-footed ferret habitat (Biggins et al. 1993), as a method of estimating population density of black-tailed prairie dogs on the Refuge. Study plots were not selected on a random basis, due to certain site characteristics needed to conduct visual counts. Site characteristics included visibility of the entire study plot from a single location, vegetation height, size of prairie dog town, and topographic relief. The number of study plots varied from year to year and was based on the number and size of prairie dog towns available. Plot size varied from 2 ha in the 1988–1990 surveys to 4–9 ha in the 1991–1994 surveys. Severe reductions in prairie dog town sizes from the 1994–95 plague epizootic limited the choice of plot sizes. Plot sizes for the 1995 surveys ranged from 0.68 to 2.16 ha and for the 1996 surveys from 0.78 to 2.25 ha. Using a surveyor's transit and geodimeter, we established plots, marking corners with 1.83-m lengths of polyvinyl chloride (PVC) tubing. Pin flags were set out at approximately 10-m intervals along plot sides to further assist in determining whether prairie dogs were in or out of the plot during counts. Visual counts were performed using a window-mounted spotting scope from a vehicle parked adjacent to the plot. Counts were conducted for 3 consecutive days on each plot, starting approximately .5 h after sunrise and continuing (with 15 min between counts) until prairie dog numbers began to decrease, usually mid-morning. The highest individual count of prairie dogs recorded during the 3 d of visual counts was then used to determine density of each plot (highest count/area). Densities were then summed and divided by the number of plots to determine mean density for each year.

RESULTS

Prairie Dog Distribution and Abundance

The distribution of prairie dog towns changed dramatically after plague events. Reductions of 95% and 99% were caused by plague epizootics in 1988–89 and 1994–95, respectively (Table 1).

Prairie dog town areas and population estimates represent peak (summer) population levels and were adjusted for the years 1992–1994 due to plague epizootics occurring before arrival of wintering raptors. Area affected by plague was subtracted from total area determined earlier in the year. Therefore, the population estimate data used in regression analyses are 10,822 (1992), 16,430 (1993), and 3,619 (1994). The area data were adjusted as well for the same time period with 608 ha (1992), 727 ha (1993), and 154 ha (1994) used in the regression analysis. These values represent a more accurate depiction of the prairie dog population available to raptors as they arrive on their wintering grounds. The 1st epizootic occurred from November 1988 to September

TABLE 1. Prairie dog population fluctuations pre- and post-plague at Rocky Mountain Arsenal NWR, 1988–1997.

Year	Mean density[a]	Study plots (*n*)	Area (ha)	Population estimate
1988[b]	20.2 ± 8.00	24	1850.8	37,406
1989[b]	20.2[c]	—	99.8	2017
1990[b]	12.2 ± 4.80	6	232.9	2842
1991	14.6 ± 3.57	9	555.6	8134
1992	17.8 ± 6.20	12	608.0	10,822
1993	22.6 ± 6.10	12	727.0	16,430
1994	23.5 ± 4.13	10	154.0	3619
1995a	50.9 ± 28.46	9	72.9	3708
1995b	50.9[c]	—	9.0	458
1996	41.1 ± 15.88	8	35.9	1478
1997	54.8 ± 26.60	6	139.8	7640

[a]Mean density ± 1 *s*
[b]1988–1990 data from Stollar et al. (1992)
[c]No density data for this year; density estimated

TABLE 2. Numbers of buteos observed during road surveys from November through March at the Rocky Mountain Arsenal NWR, 1988–1997.

Year	Number of surveys	RTHA[a]	RLHA	FEHA
1988–89	17	6.6 (6.0)[b]	4.0 (2.5)	34.1 (20.8)
1989–90	12	3.0 (4.6)	4.9 (2.1)	3.8 (2.2)
1990–91	19	4.8 (2.2)	2.7 (1.8)	2.6 (1.6)
1991–92	16	4.0 (2.8)	4.6 (2.6)	6.7 (4.1)
1992–93	16	4.2 (2.5)	3.7 (2.4)	8.7 (4.7)
1993–94	16	6.4 (2.8)	4.1 (1.6)	10.3 (3.6)
1994–95	13	2.8 (1.3)	1.9 (1.4)	3.8 (2.2)
1995–96	15	6.1 (6.9)	1.1 (1.0)	1.6 (1.5)
1996–97	16	7.0 (3.4)	5.6 (4.0)	2.7 (1.9)

[a]Standardized AOU notation
[b]Mean value (*s*)

1989, reducing the town area by 95%, and the 2nd from June 1994 to July 1995, reducing the town area by 99%. Recovery of prairie dog populations following these epizootics was facilitated by relocations from off-Refuge sources.

Raptor Surveys

Mean values of Ferruginous and Red-tailed Hawks declined after the first prairie dog plague epizootic, while Rough-legged Hawks increased following the die-off (Table 2). Rough-legged Hawks fluctuated throughout the study period. Red-tailed Hawks showed an initial rise in mean values in 1990–91, before dropping again in 1991–92. Red-tailed Hawks also showed a rapid rise near the end of the study period. Ferruginous Hawks increased steadily after the large drop in 1989 through 1991 ($\bar{x} = 34.1 \pm 20.8$ in 1988–89; $\bar{x} = 2.6 \pm 1.6$ in 1990–91), until 1994–95, when the prairie dog population again experienced a massive plague epizootic. The drop in numbers of Ferruginous Hawks in 1994–95 was almost identical to the drop in 1989–90 and then hit an all-time low in 1995–96 ($\bar{x} = 1.6$), before rebounding in 1996–97.

There was no significant correlation between counts of Red-tailed or Rough-legged Hawks and prairie dog area ($r^2 = 0.11$, $P = 0.377$ and $r^2 = 0.04$, $P = 0.612$, respectively), density ($r^2 = 0.25$, $P = 0.171$ and $r^2 = 0.07$, $P = 0.501$, respectively), and minimum estimated prairie dog population ($r^2 = 0.15$, $P = 0.305$, and $r^2 = 0.03$, $P = 0.623$, respectively). Ferruginous hawk/minimum estimated prairie dog population ($r^2 = 0.97$, $P < 0.001$) and Ferruginous Hawk/prairie dog area ($r^2 = 0.96$, $P < 0.001$) are the only portions of the model showing significance (Fig. 1).

DISCUSSION

Ferruginous Hawks are known to specialize on ground squirrels and lagamorphs (Wakeley 1974, 1978, Blair and Schitoskey 1982, Gilmer and Stewart 1983, Johnsgard 1990). Cully (1991) found that numbers of Ferruginous Hawks are closely associated with local distribution of prairie dogs during fall migration. A similar spatial relationship was found in the 1988–89 plague epizootic on the Refuge. As plague eliminated large colonies on the eastern side of the Refuge, higher numbers of Ferruginous Hawks were found on the remaining healthy prairie dog colonies in the northwestern portion of the Refuge.

These data indicate that distribution of Ferruginous Hawks on the Refuge is based on areal distribution of prairie dogs rather than prairie dog density. Minimum estimated population was also significant, but it is calculated as a product of areal distribution and density, implicating areal distribution as the major factor in determining significance. Dramatic changes in prairie dog density failed to elicit a significant response by Ferruginous Hawks. There may be some lower threshold density for black-tailed prairie dogs that would elicit a negative response (or lack of response) by Ferruginous Hawks, but it does not show up in these data. One would expect predators to respond to variations in density of prey, but in this case prairie dogs, even at relatively low densities (1990–91, 12.2–14.6 ha^{-1}), may be more available to these raptors than other

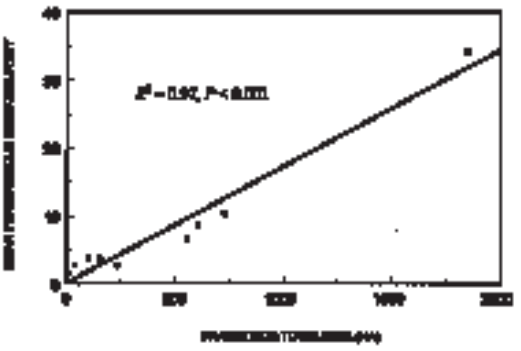

Fig. 1. Linear regression of mean Ferruginous Hawks per survey versus prairie dog town area (ha) from 1988–89 through 1996–97 at Rocky Mountain Arsenal NWR.

prey resources. The other factor that may contribute to poor performance of density in the model is that density was estimated, rather than actually measured, for 2 of the sample periods (1989 and 1995b). However, it is believed that these are reasonable estimates of actual densities and are therefore included in the analysis.

Density on prairie dog towns increased significantly in 1995–96, from $\bar{x}$ = 23.47 (*s* 4.13) in 1994 to $\bar{x}$ = 50.86 (*s* 28.46) in 1995, and $\bar{x}$ = 41.16 (*s* 15.88) in 1996. This resulted mainly from large reductions in prairie dog area due to plague and a concurrent wet year in 1995. These 2 factors acted together to force the reduced number of prairie dogs onto smaller areas where they could keep vegetation clipped short to facilitate predator detection. This hypothesis is supported by studies in which deferred grazing (increasing the height of vegetation) by cattle reduced the size and extent of prairie dog towns, with a concurrent rise in density (Knowles 1982, Uresk et al 1982, Uresk and Bjugstad 1983, Cable and Timm 1988). One would expect to see a lower threshold value (very low numbers of prairie dogs) that would fail to elicit a response by Ferruginous Hawks. The low prairie dog town area observed in September 1995 (9.0 ha), with a mean of 1.6 (*s* 1.5) Ferruginous Hawks, was probably very close to this threshold value. Therefore, it would appear that prairie dog area is the most significant part of the model explaining the response of Ferruginous Hawks. This response was observed through 2 separate cycles of plague epizootics in prairie dogs, further increasing the validity of the model. The power of this model may allow some predictive exercises to be made. Based on the data, an extrapolation to predict a lower size limit of a prairie dog town that would elicit a response from a single Ferruginous Hawk is 5.6 ha/Ferruginous Hawk (based on 1995–96 Ferruginous Hawks, $\bar{x}$ = 1.6, *s* 1.5; and prairie dogs, 9.0 ha.). This model is further supported by data collected in the Denver metropolitan area (Plumpton 1996), which show Ferruginous Hawks using small, isolated prairie dog towns.

Red-tailed and Rough-legged Hawks are more diverse in their prey selection, and changes in prairie dog distribution and abundance on the Refuge did not result in a substantial response by these species. Changes in the relative abundance of these species on the Refuge are probably tied more to variations in abundance and availability of small mammals on wintering areas.

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