THE INFLUENCE OF HIGH GROUND SQUIRREL DENSITIES ON THE OCCURRENCE OF GOLDEN EAGLES ON ALTAMONT OWNERSHIP CONSORTIUM PROPERTY

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On the basis of foot surveys along the rows of wind turbines at the Altamont Pass Wind Resource Area (WRA) of California, Orloff and Flannery (1992) estimated that about 40 golden eagles (*Aquila chrysaetos*) are annually killed, principally by turbine blade strikes. Reports by Kenetech employees and others of 26 turbine-killed eagles in 1993 and 29 in 1994 within the WRA provide support for that estimate and suggest the possibility of even higher numbers of casualties. Because golden eagles are slow to reach maturity and reproduce less rapidly than most raptors, the U.S. Fish and Wildlife Service and others have expressed concern for the welfare of the population. Golden eagles are classified as a Species of Special Concern in California and are protected under the federal Bald Eagle Protection Act.

In January 1994, the Predatory Bird Research Group (PBRG) began a field investigation to estimate the impact of the turbine kills on the demographic trend of the population. The work, funded by Kenetech and by the National Renewable Energy Laboratory (NREL), centered on estimating survival and reproductive rate. Methods included the aerial monitoring of a large sample of radio-tagged eagles and an annual survey of breeding pairs. Results, detailed in two

progress reports to NREL (Hunt et al. 1995,1996) and a final report soon to be completed, reveal a variety of human-related mortality agents operating upon the population, including turbine strikes, electrocutions, wire strikes, and lead poisoning, vehicle collisions, etc. (see below). Of 52 fatalities among the radio-tagged eagles recorded throughout the region through June 1997, at least 34 (65%) were human related. Twenty-six (50%) resulted from electrical generation or transmission (17 turbine blade strikes and 9 electrocutions). None of the electrocutions were in the WRA.

Figure 6.1. Fatalities of 52 Golden Eagles Radio-tagged in the Diablo Range
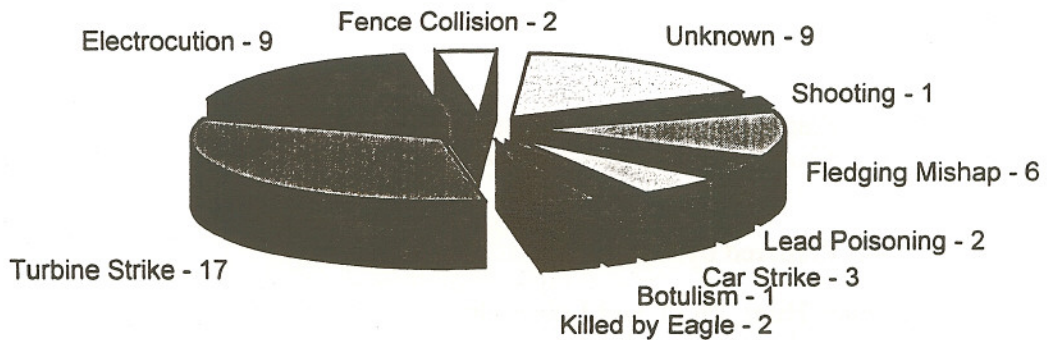
While investigating ways to reduce the rate of turbine-related mortality, Kenetech has experimented with increasing the conspicuity of turbine blades and with preventing eagles and other raptors from perching on the towers. Whether such measures would prove effective remains unknown, and equipment modifications may take several years to implement after corrective features are identified. An interim strategy would be to identify the factors attracting golden eagles to the WRA and to modify those factors in ways that would reduce the attraction. If, for example, prey were determined to be the primary reason golden eagles occur in the WRA, reducing prey numbers in the vicinities of the turbines might have the effect of reducing the numbers of eagle fatalities. Another solution might be to modify habitat factors affecting prey vulnerability, e.g., prey visibility or access to eagles, around the turbines.

During the course of PBRG's investigation, it soon became apparent that California ground squirrels (*Spermophilus beecheyii*) were the primary prey of golden eagles in the area. Of 339 prey items collected from golden eagle nests in the study area, the California ground squirrel comprised 69 percent of prey numbers and 64 percent of prey biomass. The next most important species were the black-tailed jackrabbit (*Lepus californicus*) at eight percent biomass and the black-tailed deer (*Odocoileus hemionus*) at six percent. PBRG researchers saw eagles attacking ground squirrels on

many occasions both within and outside the WRA, the primary foraging mode being "contour hunting" in which the eagles glide low along the hillsides, surprising squirrels at close range. On windy days, these coursing flights along the turbulent ridges where wind machines are situated may render eagles especially vulnerable to collisions with turbine blades. Although no blade collisions have been witnessed, we have seen eagles fly close to the moving blades and even pass between adjacent turbine towers at or near blade level. These observations suggest that golden eagles are not appropriately aware of the danger associated with wind turbines.

This report describes our preliminary results and conclusions regarding the hypothesis that golden eagles are attracted to areas of high ground squirrel density in the WRA and that, as a result of this attraction, higher numbers of eagles are killed in such areas.

Methods

Radio-telemetry. From January 1994 to July 1996 we radio-tagged 179 golden eagles within about 30 km of the WRA. Of these, there were 79 juveniles (<1 year old), 45 subadults (1-3 years), 17 floaters (non-territorial adults), and 38 breeders (territory-holders). The effective samples in the advanced age categories enlarged during the study because surviving juveniles became subadults one year after fledging, near-adults survived to become adults, and several itinerant eagles became territorial. Each transmitter was designed to operate for at least four years and was equipped with a "mortality switch" controlling the pulse rate, a feature that allows the ready detection of fatalities.

Weather permitting, we conducted roll-call censuses of the study area once per week by airplane, beginning 14 January 1994. For this purpose we used a single engine Cessna (Skylane 182) fitted with side-facing antennas on the wing struts and a switch box in the cabin enabling separate monitoring of antennas. In each survey flight, we scanned all transmitter frequencies along a course designed to locate all the birds in the sample. The surveyed area extended from the Oakland Hills south through the Diablo Range to San Luis Reservoir. We recorded eagle locations by means of a GPS receiver and mapped the relocations on digitized habitat maps with Atlas GIS software.

Ground Squirrel Surveys. We conducted a visual survey of ground squirrels within the Kenetech Wind Area (KWA) in Alameda and Contra Costa Counties. From 14 to 26 June 1997, two teams drove all accessible roads daily at 10-15 mph within the KWA and counted (with hand counters) every ground squirrel visible to the unaided eye. We surveyed during times of assumed high above-ground activity so that counts would more accurately reflect actual numbers. In earlier (1994) surveys by PBRG, we found that above-ground squirrel activity was highest in the morning (once sunlight was upon burrows) and early evening (after midday temperature declined), so long as temperatures remained below 90 degrees. Based on these preliminary observations, we performed the surveys from 0700 to 1200 hours and at 1600 to 1900 hours. Survey hours varied according to weather conditions; surveys were not conducted on afternoons when temperature exceeded 95 degrees.

Each two-person team surveyed each area at least once. In general, the two teams surveyed two different areas simultaneously; with one team in an area of suspected or confirmed high ground squirrel numbers, and the other in an area of suspected low ground squirrel concentration. We

counted ground squirrels on either side of the vehicle, each surveyor scanning his or her respective side. We recorded mileage, temperature, and other factors at the threshold of each surveyed area and at subsequent intervals defined by obvious landmarks, e.g., fences, buildings, or towers. Survey segments varied in size. When it was apparent that squirrels were clustered, segments greater than approximately 0.6 mile were reduced to reveal these local concentrations. We transferred ground squirrel density data and golden eagle sightings to detailed maps of the KWA.

We began by surveying the entire KWA twice. Each survey segment was then categorized as containing either high, moderate, or low numbers of ground squirrels, while areas of poor visibility, e.g., due to high, dense vegetation, were identified and excluded from categorization. High-density areas were defined as those where more than 12 ground squirrels were counted per 0.3 mile, and low areas as those with less than 3 seen per 0.3 mile. We conducted additional surveys (3-5) in medium-density segments and some in low-density segments to isolate ground squirrel concentrations within the area and/or to validate designations. For example, a high-density population might have initially been scored at a lower value because an unseen disturbance (predator, car) prior to our arrival caused squirrels to go into burrows. The reason for conducting the additional surveys was apparent in the behavior of squirrels we surveyed. As we drove along, squirrels typically ran for their burrows or stood erect and made alarm calls when we drove toward them. In one instance, we heard alarm calls and saw burrows and runways, but the count indicated a low- to medium-density of squirrels. We saw two eagles soaring in the area prior to our arrival which remained throughout the survey. The second time we surveyed this area, a high count was made. Counts were generally higher during the weekends when less people, e.g., windsmiths, were on site.

In summary, we based final determinations of low, medium, and high ground squirrel densities on the highest numbers observed in each area, irrespective of a lower count on a different day. Our rationale was that high counts were proof of high numbers of ground squirrels. In cases where areas designated as medium- and low-density may have actually contained higher numbers of ground squirrels, we tried to minimize the bias with repeated surveys, especially in areas exhibiting runways or other signs of ground-squirrel activity.

Statistics. To test for a relationship between ground squirrel and eagle distribution in the KWA, we selected five areas of high ground-squirrel density and five of low density. Using the GIS mapping software, we then created circles with 2.0 km diameters centering on the selected areas. Next, we overlaid the relocation points for all radio-tagged subadults and floaters located in the airplane surveys from September 1996 through June 1997. We counted the number of eagle relocations in each circle and subjected the series to several nonparametric statistical tests, including the Wilcoxon signed rank test, the null hypothesis being that there is no difference in eagle relocation frequency between areas of high and low ground squirrel densities.

Results and Discussion

Trend in Eagle Distribution: When we began the study in 1994, we recorded golden eagles in comparable numbers in both the northern and southern portions of the WRA. For example, the 249 eagle sightings we recorded in road surveys during May to November 1994 were distributed

throughout most of the WRA (Figure 1). Likewise, during the 1994 aerial surveys, we obtained many relocations of radio-tagged eagles in both the northern and southern portions of the WRA. However, as the study progressed, we detected a smaller proportion of the radio-tagged sample in the southern portion of the WRA (Figure 2). The proportion of relocations recorded in the southern WRA declined from 0.32 in 1994 to 0.16 in 1997. The four maps in Appendix 1 show change that has taken place in the relocation data during the four years, 1994-1997. In viewing these maps, remember that sample sizes of radio-tagged eagles increased through 1996.

Trend in Kill Distribution. The trend of these observations is also reflected in the distribution of golden eagle casualties resulting from turbine strikes as reported by Kenetech. During 1994 and 1995, there were 11 casualties on the Mulqueeny Ranch in the southern KWA and 23 on the Walker/Jackson/CCWD ranches in the northern KWA. In 1996 and 1997 (to date), there were 2 casualties recorded on the Mulqueeny Ranch and 18 on the northern ranches.

An Initial Search for an Explanation. We wondered if the perceived changes in the distributions of radio-tagged eagles and eagle casualties might be caused by differences in ground squirrel densities in the northern and southern portions of the WRA. Therefore, beginning at 1248 hrs. on June 4, 1997 (cloudy, temperature 71-76 degrees F), we conducted a 22-minute visual survey for ground squirrels on all major roads of the Mulqueeny Ranch south of Patterson Pass Road and observed one ground squirrel. We quickly traveled north to the Jackson Ranch, beginning our survey at 1330 hrs. We counted 136 ground squirrels in 21 minutes (partly cloudy, temperature 71-74 degrees). These observations agreed well with current relocation data of radio-tagged eagles: we had recorded very few on the southern Mulqueeny ranch for many months.

The next day, Hunt phoned Mrs. Lorie Cornwell, the manager of the Mulqueeny properties. She explained that the ground squirrel control program normally in place on the ranches had lapsed in 1994 but had been resumed in late summer 1995. As a matter of interest, in conversing with Mr. Jim Smith, the agricultural biologist for Alameda County, Lougheed learned that farmers and ranchers throughout the region practice ground squirrel control, doing so with anticoagulants administered each summer.

KWA Ground Squirrel Survey. The ground squirrel surveys conducted throughout the KWA during 14 - 26 June 1997 revealed dramatic area differences in squirrel densities. Not surprisingly, the surveys confirmed the conclusion suggested in our brief, earlier surveys that densities were very high on the Jackson and Walker ranches and the Contra Costa Water District in the northern portions of the KWA, and very low on the Mulqueeney ranches in the southern portion. Moreover, there were other identifiable areas of high and low squirrel densities throughout. These results presented an opportunity for comparison with the golden eagle relocation data obtained during our aerial surveys.

We selected ten circles in the KWA, each 2-km in diameter. Five were characterized as containing a high-density of ground squirrels and five contained low densities. We then counted the number of eagle relocations (subadults and floaters only) recorded from September 1996 through June 1997 in each of the ten circles. The null hypothesis in these comparisons was that there was no difference between the number of eagle relocations in high and low density squirrel

Figure 1

Sightings of Golden Eagles

During Road Surveys in the WRA

May - Nov 1994

WRA

Segment Boundaries

Turbine Strings

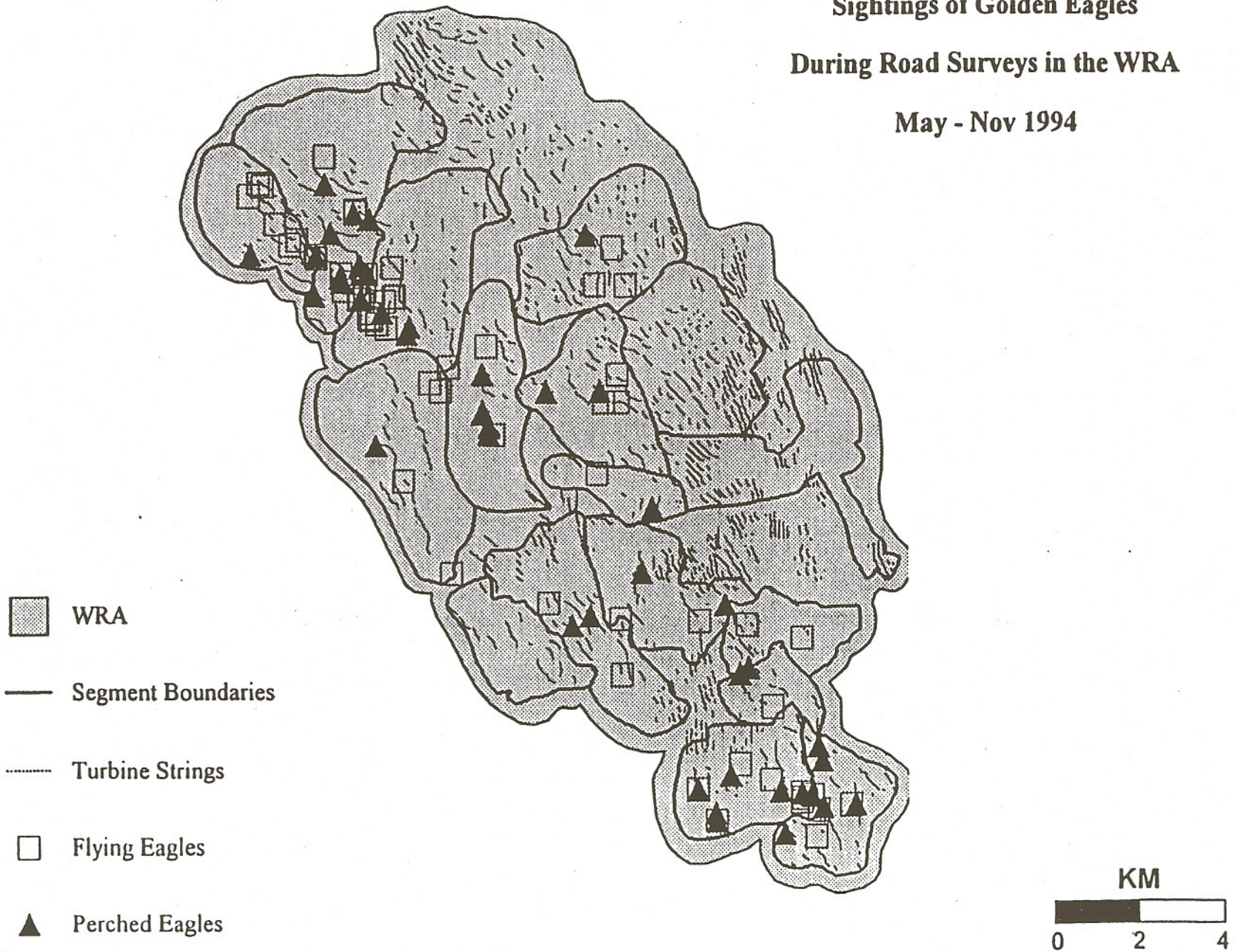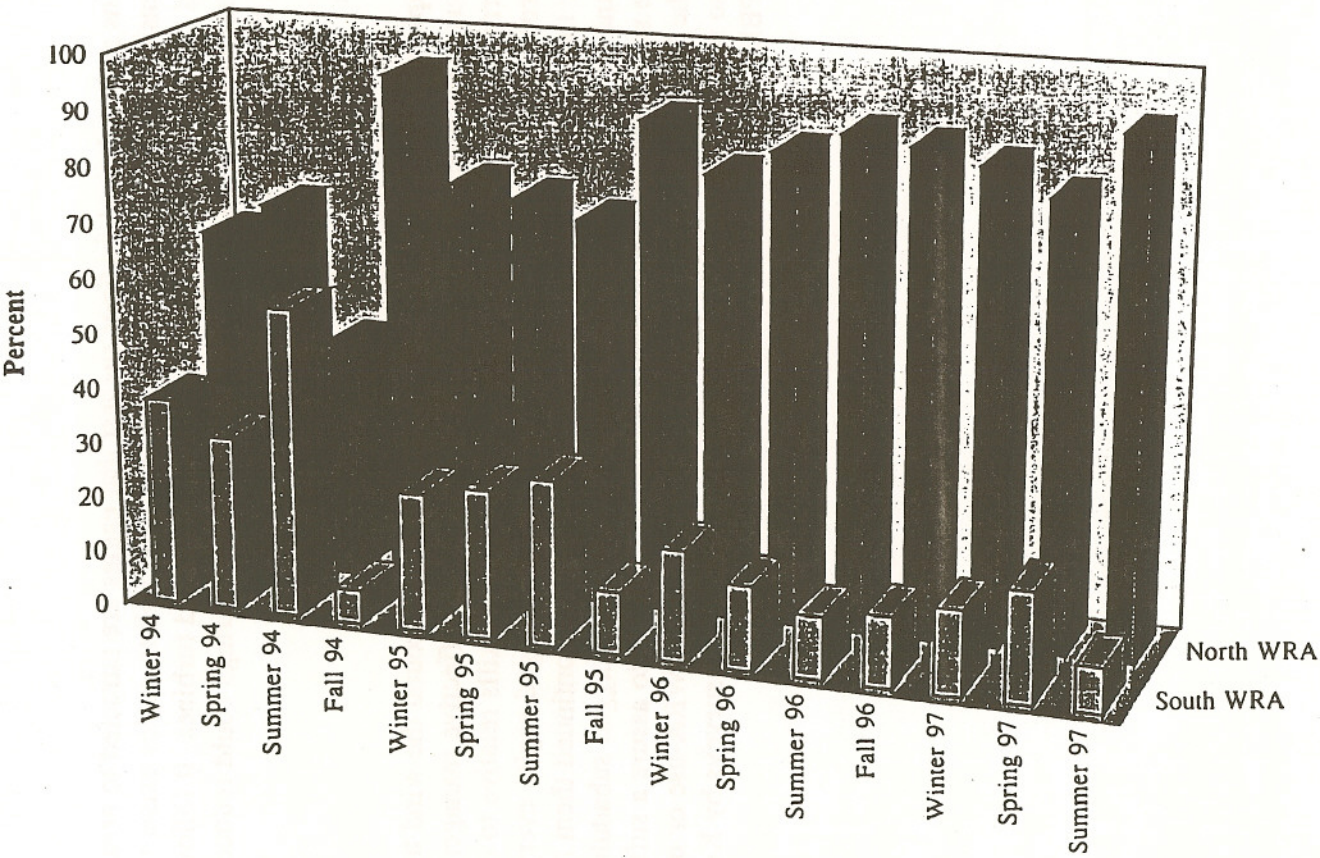Flying Eagles

Perched Eagles

KM

0   2   4

Figure 2

Percent of Itinerant Golden Eagle Relocations
in the North and South WRA Per Season
January 1994 - July 1997

plots. The results were as follows: in the high density squirrel plots there were 9, 39, 26, 13, and 10 eagle relocations, and in the low density areas there were 0, 3, 0, 2, and 1 relocations. The several nonparametric tests were all significant in relating squirrel density with eagle relocations (Appendix 2).

Conclusion

All our observations and analytical findings suggest that eagles are attracted to areas of high ground squirrel density in the WRA. Obviously, an increased risk to eagles exists where high numbers of ground squirrels frequent the vicinities of active wind turbines. It follows that a reduction in the number of ground squirrels around the turbine strings could reduce the number of eagles present and thereby reduce the number of blade strike kills.

Recommendation

If a program is implemented to control ground squirrel densities around the wind turbines, it is highly advantageous to document the influence of this potentially effective management action on golden eagle occurrence in the WRA and the rate of turbine strike kills relative to eagle occurrence. We propose to continue the aerial surveys for radio-tagged eagles every two weeks. NREL support for these surveys ceased in mid-June 1997, but we continued them through September with funding from Kenetech. There are still 40-50 radio-tagged subadults and floaters spread through the study area, but we propose doubling this sample to assure a sufficient number of relocations in the WRA vicinity for the accurate determination of WRA-use or non-use. The analysis would also require periodic repetition of the ground squirrel surveys by Kenetech employees or by PBRG if needed.

Appendix 1

Relocations of radio-tagged subadults and floaters in relation to the WRA

Relocations of Itinerant Golden Eagles

In the Vicinity of the WRA

1994

KM

0   1   2
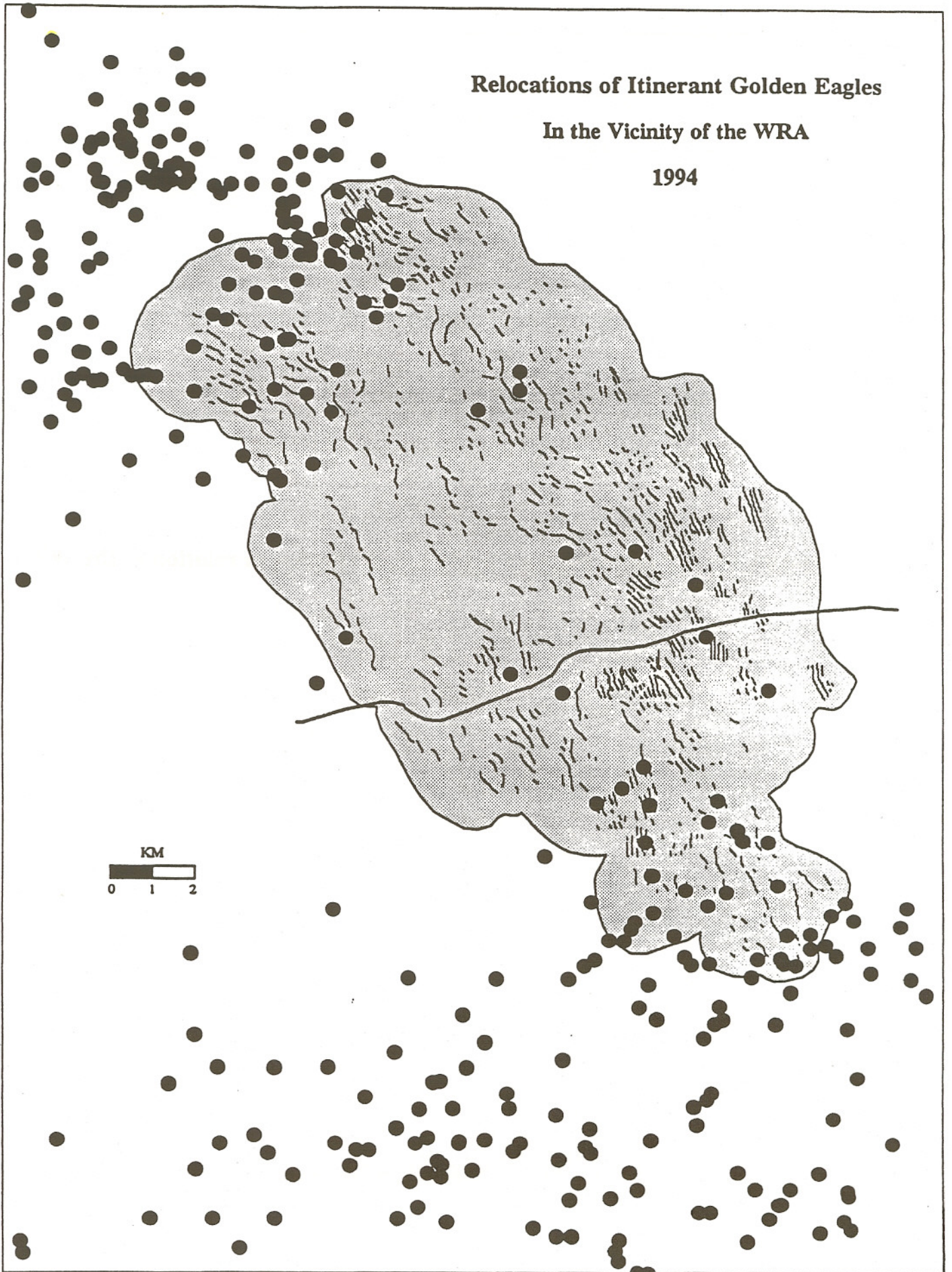
Relocations of Itinerant Golden Eagles
In the Vicinity of the WRA
1995

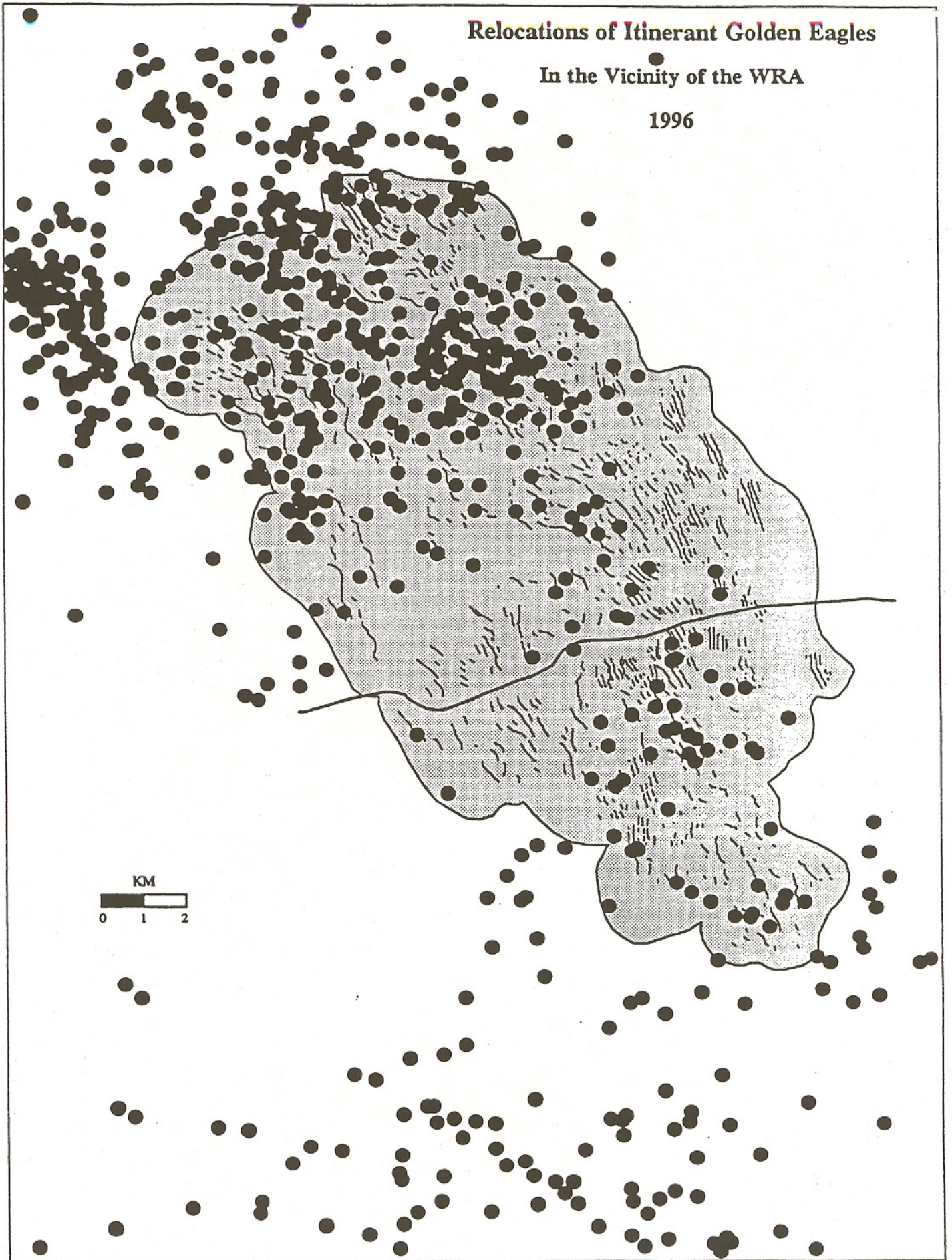Relocations of Itinerant Golden Eagles
In the Vicinity of the WRA
1996
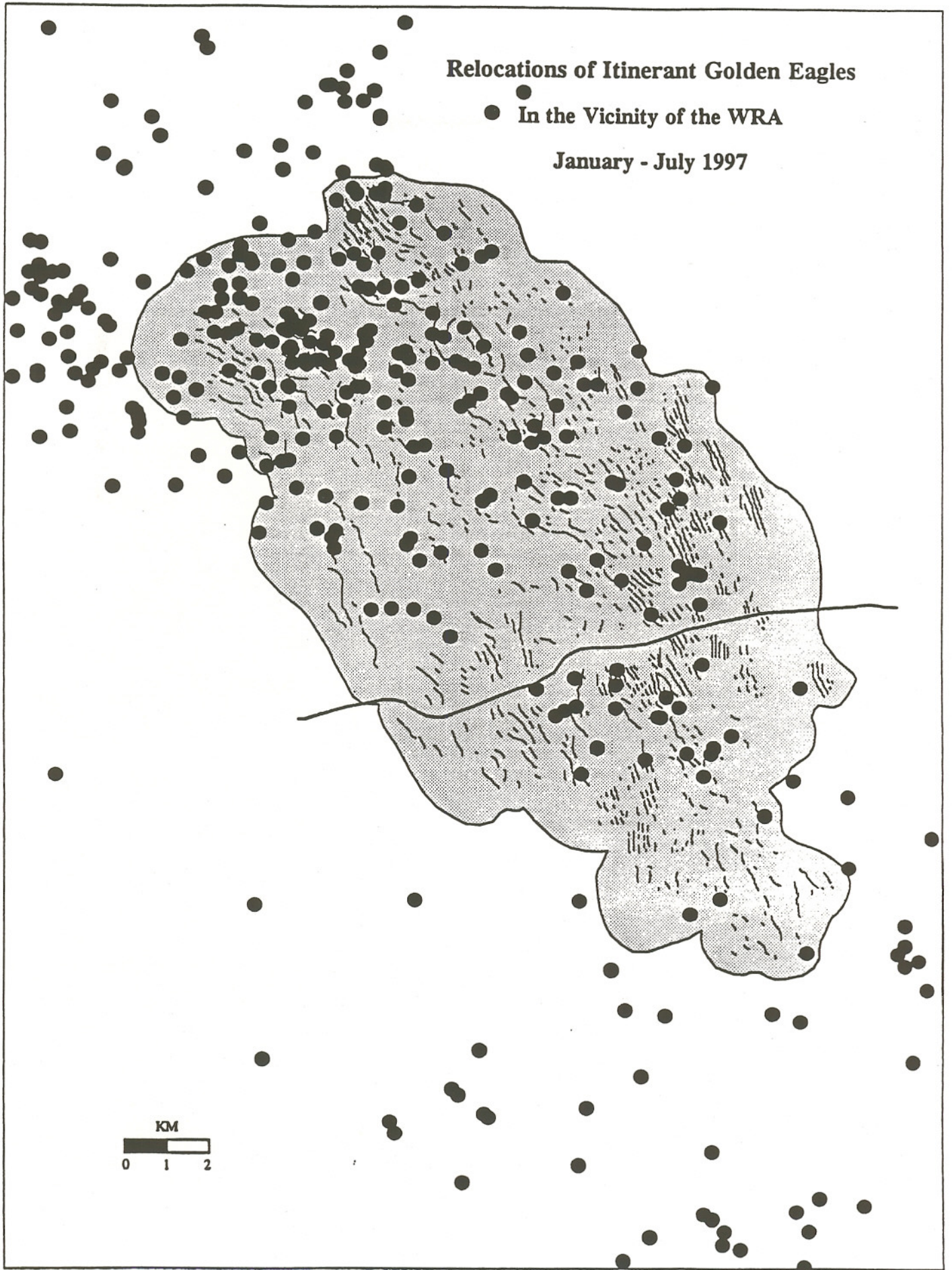
KM
0   1   2

Relocations of Itinerant Golden Eagles

In the Vicinity of the WRA

January - July 1997

KM

0   1   2

Appendix 2

Results of statistical tests relating the occurrence
of radio-tagged eagles to ground squirrel abundance

Analysis of Variance for Variable EAGLE
Classified by Variable TRT

TRT	N	Mean	Among MS
Within MS			
			828.100000
84.0000000			
2	5	19.4000000	
1	5	1.2000000	F Value
Prob > F			
			9.858
0.0138			

Average Scores Were Used for Ties

Wilcoxon Scores (Rank Sums) for Variable EAGLE
Classified by Variable TRT

		Sum of	Expected	Std Dev
Mean				
TRT	N	Scores	Under H0	Under H0
Score				
2	5	40.0	27.5000000	4.77260702
8.0				
1	5	15.0	27.5000000	4.77260702
3.0				

Average Scores Were Used for Ties

Wilcoxon 2-Sample Test (Normal Approximation) (with Continuity Correction of .5)
$S = 40.0000$ $Z = 2.51435$ Prob > |Z| = **0.0119**

T-Test Approx. Significance = **0.0331**

Kruskal-Wallis Test (Chi-Square Approximation) CHISQ=6.8598; DF=1 Prob>CHISQ = **0.0088**

Median Scores (Number of Points Above Median) for Variable EAGLE
Classified by Variable TRT

Mean TRT	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Score
2	5	5.0	2.50000000	0.833333333	1.0
1	5	0.0	2.50000000	0.833333333	0.0

Average Scores Were Used for Ties

Median 2-Sample Test (Normal Approximation)
S = 5.00000; Z = 3.00000; Prob > |Z| = **0.0027**

Median 1-Way Analysis (Chi-Square Approximation)
CHISQ = 9.0000; DF = 1; Prob > CHISQ = **0.0027**

Van der Waerden Scores (Normal) for Variable EAGLE
Classified by Variable TRT

Mean TRT	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Score
2	5	3.31116194	0.0	1.30440814	0.662232388
1	5	-3.31116194	0.0	1.30440814	-.662232388

Average Scores Were Used for Ties

Van der Waerden 2-Sample Test (Normal Approximation)
S = 3.31116   Z = 2.53844   Prob > |Z| = **0.0111**

Van der Waerden 1-Way Analysis (Chi-Square Approximation)
CHISQ = 6.4437; DF = 1; Prob > CHISQ = **0.0111**

Savage Scores (Exponential) for Variable EAGLE
Classified by Variable TRT

TRT	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
2	5	3.22817460	0.0	1.40087858	0.645634921
1	5	-3.22817460	0.0	1.40087858	-.645634921

Average Scores Were Used for Ties

Savage 2-Sample Test (Normal Approximation)
S = 3.22817   Z = 2.30439   Prob > |Z| = 0.0212

Savage 1-Way Analysis (Chi-Square Approximation)
CHISQ = 5.3102   DF = 1   Prob > CHISQ = **0.0212**

Kolmogorov-Smirnov Test for Variable EAGLE
Classified by Variable TRT

TRT	N	EDF at Maximum	Deviation from Mean at Maximum
2	5	0.0	-1.11803399
1	5	1.0	1.11803399
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	10	0.5	

Maximum Deviation Occurred at Observation   7; Value of EAGLE at Maximum 3.00000000

Kolmogorov-Smirnov 2-Sample Test (Asymptotic)
KS = 0.500000   D = 1.00000
KSa = 1.58114   Prob > KSa = 0.0135