The Effects of Predator Exclusion and Food Supplementation on Burrowing Owl (*Speotyto cunicularia*) Population Change in Saskatchewan

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Abstract.—If low reproductive output plays an important role in the population decline of the Burrowing Owl (*Speotyto cunicularia*) in Canada, we predicted the decline would slow or stop in our study population after consecutive years of productivity enhancement via food supplementation and predator exclusion. In the portion of our study site for which historical data existed, the yearly rate of decline averaged 24.7 percent per year before, and 11.8 percent per year after, productivity enhancement. Our overall study population showed no decline after the first year of treatment, but declined 17 percent following the second year of treatment. Females (both adults and juveniles) showed lower site fidelity and dispersed farther than did males, and juveniles showed lower site fidelity and dispersed farther than did adults. Although adult dispersal distances were small, natal dispersal distances suggest that emigration probably occurs from our study area, increasing the difficulty of detecting a population effect from our treatment.

The Burrowing Owl (*Speotyto cunicularia*) is designated as an Endangered species in Canada because of its severe and ongoing population decline (Hjertaas et al. 1995, Wellicome 1997a, Wellicome and Haug 1995). Habitat modification, resulting from the steady increase in intensity of agricultural land-use, is the factor reported to be ultimately responsible for this decline (Haug and Oliphant 1990, Hjertaas et al. 1995, Schmutz et al. 1991, Wedgwood 1978, Zarn 1974), but proximate factors have yet to be identified (Haug 1985, James and Fox 1987, Wedgwood 1978).

Proximate factors can cause population declines by reducing either recruitment (the number of first-time breeders) or survival of adults, or both (Temple 1986). Canada's Burrowing Owls spend their winters in unknown areas at least as far south as Texas or Mexico (James 1992), and their degree of philopatry to breeding areas has not been measured adequately; hence, it is not yet possible to calculate accurate annual survival rates for adult owls. On the other hand, one important component of recruitment—reproductive output—is determined entirely within the breeding grounds, and has been quantified for several years on two study sites in Canada. The number of young fledged per successful nest has declined significantly over the last decade near both Hanna, Alberta (J.K. Schmutz, unpubl. data), and Regina, Saskatchewan, as has the number of fledglings per nesting attempt in Saskatchewan—the only area for which those data exist (James et al. 1997). However, a causal relationship between the observed decline in reproductive output and the decline in population size has not been established.

Predation and food shortage are factors that often limit reproduction in birds and other animals (Martin 1992, McNamara and Houston 1987). Because Burrowing Owls are small ground-nesters, they have many predators: badgers (*Taxidea taxus*), foxes (*Vulpes* spp.), striped skunks (*Mephitus mephitus*), weasels (*Mustela nivalis* and *M. frenata*), and raccoons

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(Procycon lotor) enter or excavate burrows and eat eggs, nestlings, and/or adult females (Wellicome and Haug 1995). On the Regina Plain, mammalian predation causes a high nest-failure rate in Burrowing Owls (P.C. James, unpubl. data), and predator exclusion has been suggested as a method to potentially increase nesting success.

Reproductive food-limitation appears to be widespread in Burrowing Owls. In Oklahoma, availability of vertebrate prey in spring was thought to limit the reproductive output of owls (Butts 1973). In Idaho, brood size increased with proximity to irrigated agricultural areas, and prey availability was again suggested as the causal factor (Gleason 1978). Preliminary results from food supplementation experiments on the Regina Plain showed that food intake during brood-rearing limited the number of fledglings produced at successful Burrowing Owl nests (Wellicome 1997b).

If low reproductive output plays an important role in the Burrowing Owl population decline, relative to potential non-breeding effects (e.g., high winter mortality), we predict the decline will slow or stop if owl productivity is successfully increased for several consecutive years in a discrete area. However, the likelihood of detecting such an effect would depend partly on the propensity of individuals to disperse and, thus, sometimes emigrate from the study area. If site fidelity were high and/or dispersal distances small, a positive population response to increased productivity would lead to a higher number of pairs within the study area. However, if site fidelity were low and dispersal distances large, a positive population response would likely not be detected inside the study area because the increased number of recruits would be spread over a wide geographic area.

Here, we present preliminary results from the first 3 years of a 5-year study. Our specific objectives were four-fold:

1. To develop and test "predator-proof" artificial nest burrows for increasing the proportion of Burrowing Owl nests that successfully raise young to fledging age.
2. To further assess the effectiveness of supplemental feeding during the nestling stage for increasing the number of young fledged from successful nests.
3. To measure nest-site fidelity and dispersal of adults and juveniles.
4. To determine if increasing the number of fledglings produced per nesting attempt in consecutive years affects the population decline.

METHODS

Burrowing Owls were studied in the Grassland Ecoregion of Saskatchewan (Harris et al. 1983) from mid-April to mid-August, 1994-1996, on a 10,000 km^2 site situated south of the cities of Moose Jaw and Regina (108 townships; one township = 9.6 x 9.6 km). The site included the area in which James et al. (1997) studied Burrowing Owls between 1987 and 1993 (fig. 1). Thus, data from our experiments can be compared to historical data from the same site. The majority of our study area lies on the Regina Plain, with the southwestern-most portion extending into the Missouri Coteau. In 1996, the study area was expanded southward to encompass an additional 2,200 km^2. Intensive cultivation in this region has left a heavily-fragmented landscape (James et al. 1990). Consequently, most owls nest in small, intensively-grazed pastures that are interspersed among a variety of habitat types, including cereal crops, summer fallow, hayland, and other grassland.

Each year within our study area, we visited all sites known to have had owls at least once in the past 5 years, as well as any newly-discovered sites. We searched pastures by driving or walking transects spaced at approximately 25 m, thus passing within 12.5 m of any potential owl burrows. All ground squirrel or badger burrows were scanned for signs of Burrowing Owl activity (whitewash or pellets). In addition, we chose randomly 5 of the 28 townships that were known to have contained at least one pair of owls in 1995, and searched all grassland fragments and roadside-ditches within this subset of townships in 1996. We found no additional Burrowing Owl nests with this intensive search method, suggesting that the method of visiting only known sites, or those sites reported to us, missed few (if any) occupied owl nests.

In May, 1 to 2 weeks after each pair had chosen a burrow and begun lining its entrance with nesting material, we installed a wooden artificial nest burrow (fig. 2) in place of the natural burrow. From ground-level, artificial nest burrows (ANBs) looked the same as natural burrows, and we lined the tunnels and nest

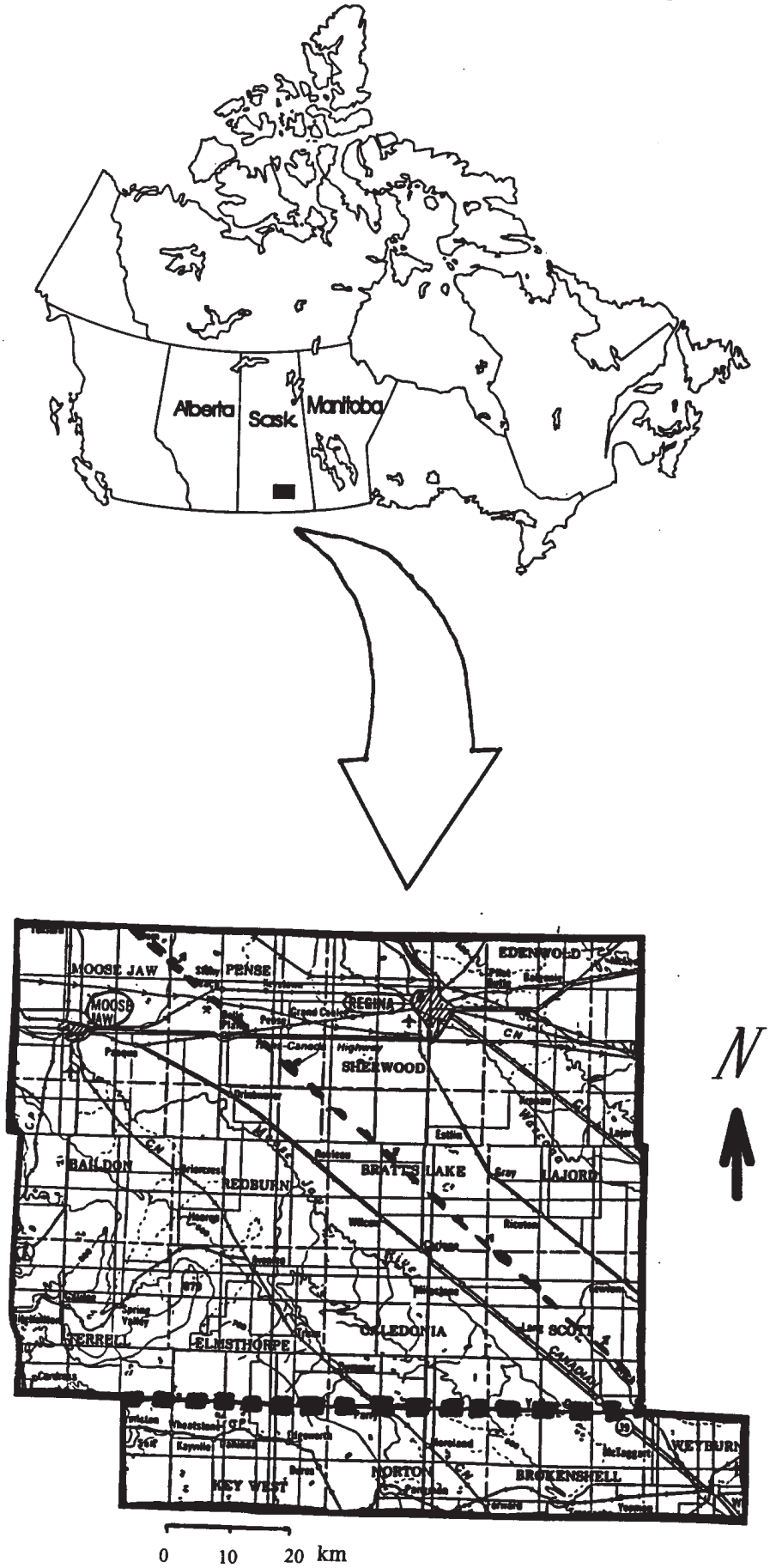
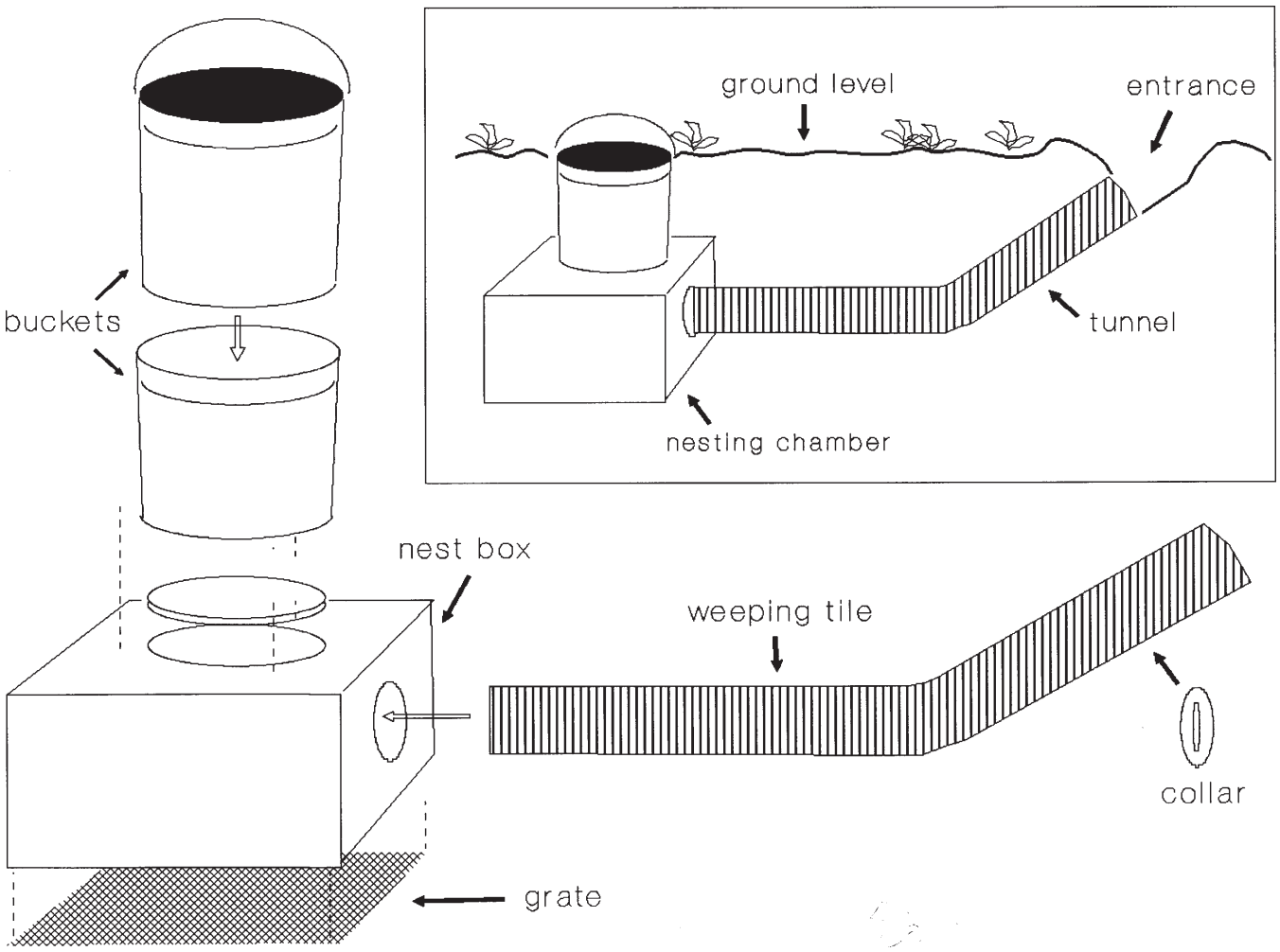


Figure 1.—Study area on the Regina Plain, Saskatchewan. The extension of the study area in 1996 is shown below the thick dashed line. Historical data were collected by Dr. Paul C. James in the northeastern portion of the study area, indicated with a thin dashed line.

chambers with dirt and shr edded, dry manure to r esemble the inside of natural burr ows. Nest boxes were intr oduced befor e egg-laying, and owls initiated their clutches in the artificial chambers a few days to a few weeks later Eggs were checked appr oximately 1 month after laying to establish hatching dates. ANBs wer e designed to be 'predator pr oof' from above (fig. 2); i.e., able to exclude fossorial (digging) predators. However, mid-way thr ough the 1994 br eeding season, we discovered that one predator—the badger—was able to access nests by digging around and then under neath the bottomless boxes. In 1995 and 1996, we covered the bottoms of most ANBs with metal grates, thus excluding badgers while still maintaining adequate drainage. Many ANBs were occupied in years subsequent to their installation, but when owls chose natural burr ows, an effort was made to install pr eda-tor-pr oof ANBs. Twenty-four of 50 nests (48 percent) in 1994, 32 of 53 nests (60 per cent) in 1995, and 31 of 52 nests (59 per cent) in 1996 were in pr edator-pr oof burr ows.

Pairs that hatched young wer e provided with supplemental food for between 40 and 50 days until family gr oups became independent of their nest burr ows. Pairs were fed at 3-day intervals, by leaving dead laboratory mice and quail in nest chambers or in burr ow entrances (Wellicome 1997b). Pairs wer e provided with food at a rate of appr oximately 85 g/nest/day, corr esponding to mor e than thr ee times the



Figur e 2.—Predator-proof artificial nest burrow (ANB) used to exclude fossorial mammalian predators from Burrowing Owl (Speotyto cunicularia) nests in the Grassland Ecoregion of Saskatchewan. ANBs were installed to replace occupied natural burrows before egg laying each year. The bucket system enables investigators to access the nest chamber, but still provides insulation from heat or cold when the dirt-filled bucket is in place.

food required for daily existence metabolism of an adult Burrowing Owl in captivity (mean = 26 g, Marti 1973). In 1994 and 1995, all nests active after hatch were provided with supplementary food (43 and 50 nests, respectively). In 1996, 43 nests (84 per cent of active nests) were provided with extra food. Nestling survival was monitored by counting chicks inside nest chambers at 6-day intervals until fledging. For nests in natural burrows, fledglings were counted at burrow entrances during three or more 30-minute observation periods late in the nestling stage.

To determine dispersal distances, we banded all nestlings produced in artificial burrows and most fledglings from natural burrows. We captured as many adults as possible, either inside nest boxes during incubation or outside natural burrows using noose carpets baited with dead quail (Bloom 1987), and gave each adult a unique combination of colored legbands. A total of 157 fledglings (67 per cent) and 37 adults (42 per cent) were banded in 1994, 158 fledglings (87 per cent) and 32 adults (31 percent) in 1995, and 187 fledglings (88 percent) and 69 adults (65 per cent) in 1996. We defined adult dispersal as the straight-line distance between the breeding site at banding and the next observed breeding site in a subsequent year (Korpimäki et al. 1987). Although most owls were sighted in consecutive years, three individuals resighted 2 years after their initial capture were also included in the analysis. We defined natal dispersal as the distance from a bird's natal site to its first observed breeding site. Most of the owls bred first when they were 1 or 2 years of age, but some of the owls included in our analysis were not observed breeding until they were 3 or 4 years of age. Owl banding began in the study area in 1985 (D.G. Hjertaas, P.C. James, and L.Scott; unpubl. data). The oldest known-age breeders were banded as adults 4 years before their last resighting and were, thus, at least 5 years of age.

All statistical tests were performed using SYSTAT for Windows (Wilkinson 1992). Two-tailed Fisher's exact tests and Mann-Whitney U-tests were used for hypotheses concerning site fidelity and dispersal distances, respectively, because effects in either direction were of interest and dispersal distances had non-normal distributions. All other tests were one-tailed because effects in only the predicted direction were meaningful to the hypotheses tested (Sokal and Rohlf 1981). Mantel-Haenszel Chi-square was used to remove effects of year when examining the relationship between predator-proofing of burrows and frequency of nest predation.

RESULTS

Productivity

To test whether the technique of food supplementation increased the number of fledglings produced per successful nesting attempt in Burrowing Owls, we present data from 3 years in which control pairs (those not receiving extra food) existed for comparison (T.I. Wellicome, unpubl. data). Pairs that were fed during the nestling period fledged 41 per cent (range: 16-192 percent) more offspring, on average, than did control pairs with only natural prey available to them (ANOVA, $P < .001$; fig. 3).

Predator exclusion in 1994 was not entirely successful because badgers were able to enter some of the ANBs. Nonetheless, 67 per cent of the nests managed to fledge at least one young in that year. Of the 19 nests in 1995 that were in natural burrows, 10 (53 percent) were lost to fossorial predators, which resulted in total reproductive failures. Of the 32 nests in ANBs that same year, 18 had predation attempts but only 3 (9 percent) failed as a result of these attempts: two burrow mouths were filled in by badgers, causing death of eggs and young chicks, and one nest was depredated by a red fox kit small enough to fit past the predator collar in the tunnel (fig. 2). In 1996, none of the 31 nests in predator-proof ANBs failed because of predation, despite several attempts at six of them; whereas, 3 of 16 natural burrows (19 percent) appeared to have been depredated. Predator-proof burrows thus significantly decreased the frequency of nest predation (Mantel-Haenszel Chi-Square statistic = 17.2, $P < .001$).

The increase in the number of fledglings, due to food supplementation, and the increase in nest success, due to predator exclusion, resulted in overall productivity of 5.0, 3.6, and 4.2 fledglings per attempt in 1994, 1995, and 1996, respectively. The average productivity in years with productivity enhancement (mean = 4.3 fledglings per attempt, SD = 0.7, N = 3 years) was substantially higher (Student t-test, $P = .03$) than the average for pre-treatment years (1986- 1993, mean = 2.6 fledglings per attempt, SD = 1.3, N = 8 years).

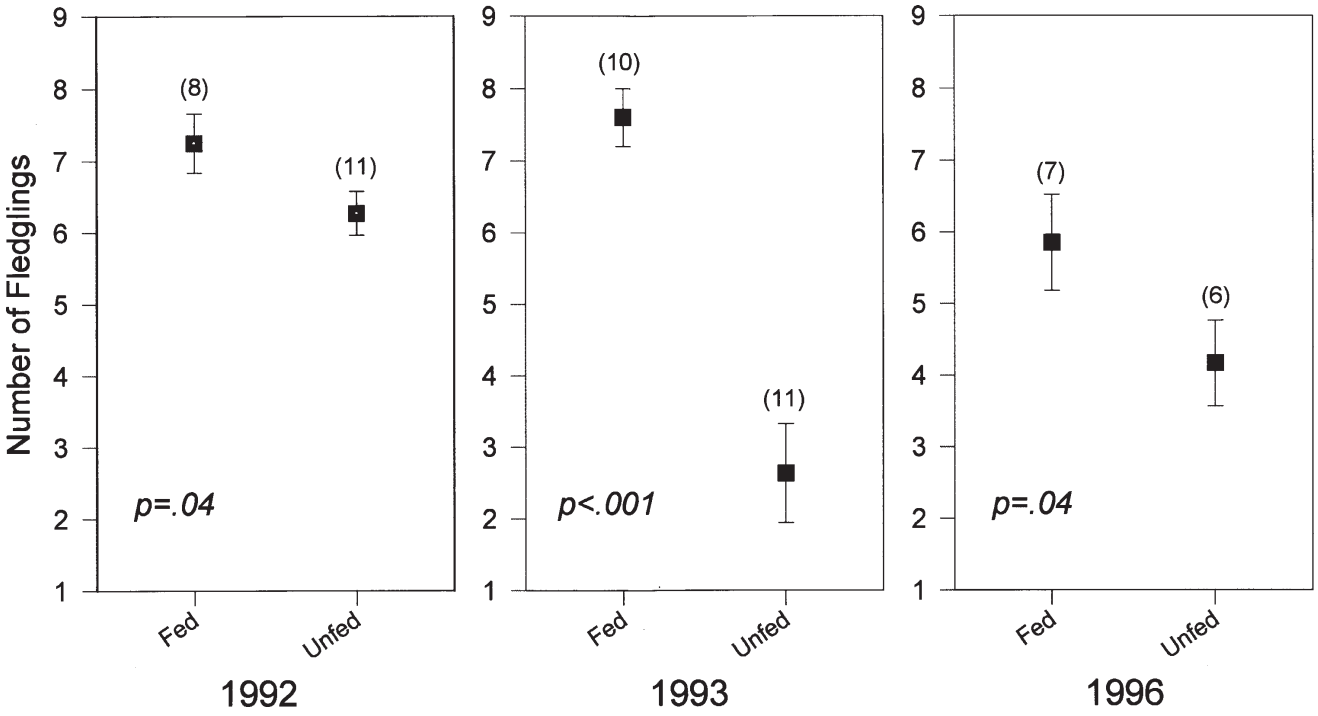


Figure 3.—Number of young fledged per successful attempt (mean and standard error) by Burrowing Owl (Speotyto cunicularia) pairs provided with extra food during brood-rearing (Fed) and by control pairs not given extra food (Unfed) in the Grassland Ecoregion of Saskatchewan. Sample sizes are shown in parentheses. Fed pairs fledged significantly more young in each of the 3 years (Student's t-tests, = 0.05), although differences varied among years. 1992 and 1993 data are from earlier experiments on the same study site (Wellicome 1997b; T.I.Wellicome, unpubl. data).

Population Change

For the northeastern portion of our study area, we compared the annual decline in per cent of the population following years of productivity enhancement (1994-1996) to the annual percent decline prior to productivity enhancement (1987-1993; fig. 4). The average, annual percent decline was greater before productivity enhancement (mean = 24.7 per cent, N = 7) than after (mean = 11.8 per cent, N = 2). This difference was statistically significant (Student t-test with separate variances, P = .04).

Over the entire study area, the population showed no decline after the first year of treatment (between 1994 and 1995; fig. 5), but declined by approximately 17 percent following the second year (between 1995 and 1996).

Dispersal

Fidelity to breeding sites (dispersal distance = 0) was high for adults in general (fig. 6a), but was higher for adult males than for adult

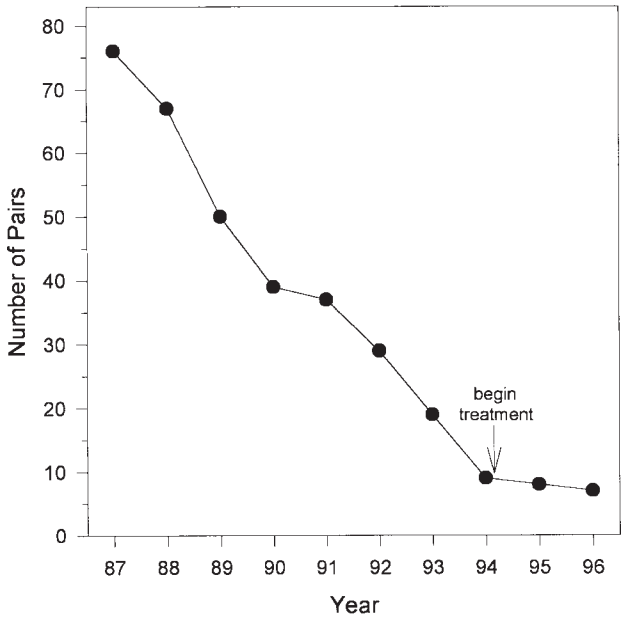


Figure 4.—Number of Burrowing Owl (Speotyto cunicularia) pairs present each year in the northeastern portion of our study site in the Grassland Ecoregion of Saskatchewan. Historical data provided by Dr. Paul C. James, Saskatchewan Environment and Resource Management.

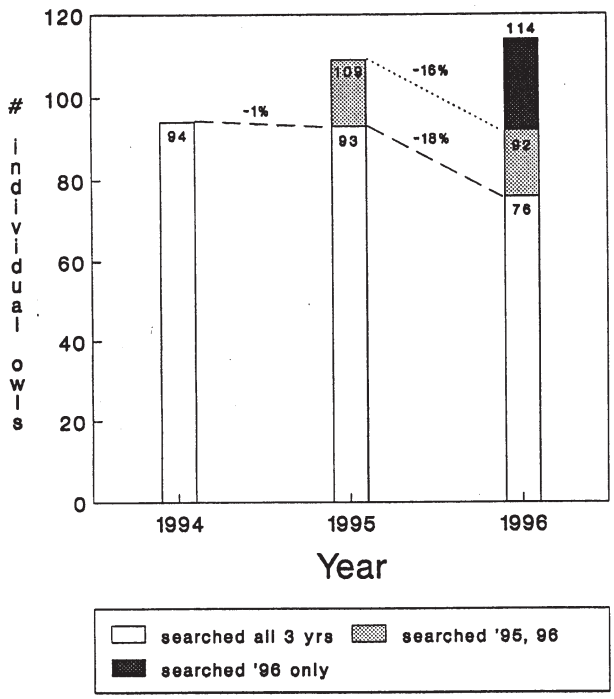


Figure 5.—Number of individual Burrowing Owls (Speotyto cunicularia) in 10,000 km² Grassland Ecoregion of Saskatchewan study site in 3 years. Food supplementation and predator exclusion began for the population in 1994. The grey bars indicate owls found on land to which we were allowed access beginning in 1995. The darkest bar in 1996 represents owls found on new land searched when the study area was expanded to the south by approximately 20 percent (based on area). Although there was no decline in the study population following the first treatment year, the population declined by approximately 17 percent following the second treatment year.

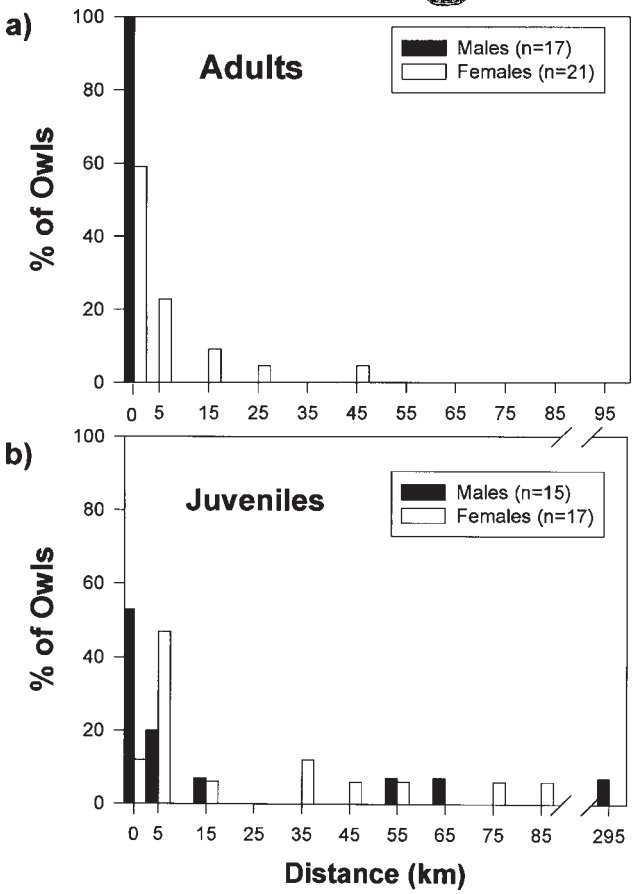


Figure 6.—Dispersal distances (presented in 10 km blocks) for all Burrowing Owls (Speotyto cunicularia) captured inside the Grassland Ecoregion of Saskatchewan study area in at least 2 different years. A distance of 0 km indicates the individual was found breeding at the same site in which it was captured in a previous year. a) Breeding dispersal distances for owls trapped as adults and retrapped or sighted breeding in a subsequent year. b) Natal dispersal distances for birds banded as nestlings and returning to breed on the study site.

females (Fisher's exact test, N = 38, P = .005). In fact, males showed absolute fidelity to their breeding sites. Consequently, adult female dispersals were of greater distance than were those of males (U = 111, N = 38, P = .005). A few females made medium-distance movements within the study area, the farthest of which was 49 km, but their were no long-distance movements by adults. In general, fidelity to nest sites was lower for juveniles (Fisher's Exact test, N = 70, P < .001) and they dispersed farther from nest sites than did adults (U = 294, N = 69, P < .001). Site fidelity was higher for juvenile males than for juvenile females (Fisher's exact test, N = 32, P = .02): over one-half of returning males bred on their natal sites, but only 12 per cent of females bred on natal sites (fig. 6b). However, nearly one-half of the females settled between 1 and 10 km from their natal site. After the exclusion of one outlying male natal dispersal of 295 km, juvenile females dispersed farther on average than did males (U = 70, N = 31, P = .05).

The direction of dispersal showed no obvious patterns for either adult females or juveniles (fig. 7). However, the interchange of owls between sites within the study area suggests

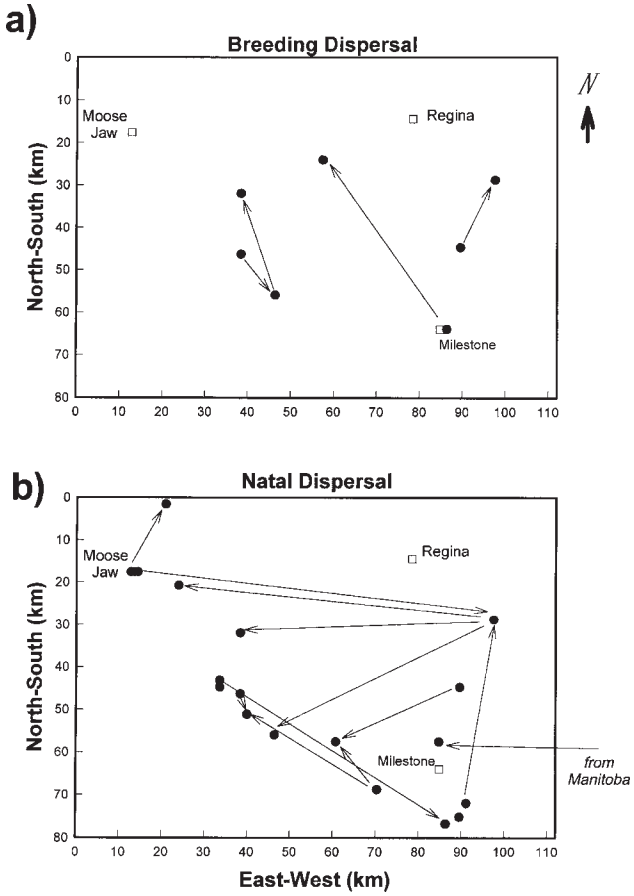


Figure 7.—Directions and distances of between-year movements greater than 2 km in the Grassland Ecoregion of Saskatchewan. The grid represents our study area. Breeding dispersals are movements of adults and natal dispersals are movements of juveniles. Solid circles indicate Burrowing Owl (Speotyto cunicularia) breeding sites where dispersal occurred, and empty squares indicate cities or towns.

that Burrowing Owl numbers on a given site are partially dependent on numbers and productivity at other sites over a large area. This is especially true for juvenile owls, whose dispersal distances were sometimes large in comparison to our study site (fig. 7b).

DISCUSSION

Dispersal distances seemed relatively large in our population, especially for juveniles. Unfortunately, there is little dispersal information available for the western Burrowing Owl with which to compare our results (Haug et al. 1993). Owls near Hanna, Alberta, showed dispersal patterns similar to ours, in that fidelity to breeding sites was higher in adult males than in females and adult females dispersed farther from their previous breeding sites than did males. However, the maximum breeding dispersal observed in Hanna was only 4 km (J.K. Schmutz, University of Saskatchewan, unpubl. data), compared to 49 km at our Regina site. Dispersal distances recorded in the Hanna area may have been smaller than those on the Regina Plain because habitat types differ considerably: the Hanna site is characterized by relatively continuous rangeland habitat. Dispersal distances for owls nesting in highly-fragmented agricultural land in Manitoba (De Smet 1997) were of similar magnitude to those measured in our study area.

The high nest-site fidelity of adults and the small dispersal distances relative to the size of our study area suggest that the number of adult owls emigrating from the area is quite small. However, emigration is likely frequent enough to make return rates within the study area slightly conservative estimates of adult survival. For example, the farthest adult dispersal recorded in Canada was of a Burrowing Owl banded near Saskatoon and recovered the following year, approximately 220 km to the southwest of its original breeding site (E.A. Haug, unpubl. data).

Natal site-fidelity was not high, and juvenile dispersal distances were sometimes large in relation to our study area. This may explain why we sometimes capture unbanded 1-year-old breeders in our study area (T.I. Wellicome, pers. observ.). The only banded bird known to have immigrated into our area, moved approximately 295 km from its natal site in Manitoba. Although this is the farthest natal dispersal recorded to date, it is not the first inter-provincial movement on record: a previous natal dispersal, between Manitoba and Regina (P.C. James, unpubl. data), was approximately 290 km. Such returns, coupled with the observations of natal dispersal across the breadth of our study site, suggest that there is immigration and emigration of juveniles to and from our study population. This means that any increase in the number of recruits resulting from productivity enhancement has probably occurred over a geographic area wider than our study site, thus 'diluting' the local population effect and reducing our chance of detecting a treatment-effect.

Notwithstanding the above, some of the evidence we collected suggests there has been a positive effect of our treatment on the Burrowing Owl population. In the portion of our study area that corresponds to P.C. James' historical study area, the rate of population change for the 2 years following the start of productivity enhancement was lower than in any of the 7 preceding years. Similarly, the rate of population decline for our overall study population was lower in the 2 years following productivity enhancement than it was in the 2 preceding years ('Avonlea' site in Wellicome and Haug 1995). In fact, the decline of 1 per cent between 1994 and 1995 is the lowest year-to-year decline ever recorded for a Burrowing Owl population in Canada where search effort was consistent each year. On the other hand, the decline of between 16 and 18 percent from 1995 to 1996 was steep, suggesting that productivity enhancement was having little effect on the decline during that period. Our next step will be to compare the yearly rate of decline inside the study area to the rate outside the study area. For these comparisons, we plan to use data from the Operation Burrowing Owl land-owner survey for the province of Saskatchewan (see Hjertaas 1997). It will also be informative to compare, on a nest-by-nest basis, re-occupancy rates following successful and failed nesting attempts to see if probability of re-occupancy can be predicted from current nesting success (cf. Sonerud 1985).

For species such as the Burrowing Owl, which are precipitously declining in numbers, it is desirable to stabilize populations by slowing or halting their decline until ultimate causes can be identified and, if possible, corrected (Temple 1986). Food supplementation and predator exclusion are short-term management techniques that immediately increase Burrowing Owl reproductive output. After 2 years of post-treatment results from productivity enhancement, we cannot conclude for certain that such techniques affect population numbers, so we hesitate to make final management recommendations until our experimental population has been monitored for a few more years. If enhanced productivity does not slow the population decline, future research should focus on mortality factors during the post-fledging, migration, and wintering periods. If, however, we can demonstrate that productivity has an important influence on the study population, we can recommend specific management activities for breeding Burrowing Owls on the prairies.

Artificially increasing productivity on a prairie-wide basis can only be viewed as a 'stop-gap' option (Temple 1986)—one that may be justified in the short-term, given the severity of the problem for this species in Canada. However, such a technique is intensive and does not present a viable long-term solution. Habitat manipulations would be more effective for increasing productivity in the long term. Predation of Burrowing Owl nests could probably be decreased by increasing populations of ground squirrels, which are alternative prey for all predators of Burrowing Owls, and by increasing the size of pasture fragments. Habitat improvement, through the planting of permanent vegetation strips in highly-cultivated regions and/or rotational grazing in heavily-grazed areas, could enhance Burrowing Owl productivity by increasing cricetid prey populations.

Results from 3 years of productivity enhancement are inconclusive thus far, but are encouraging nonetheless. Data presented here are the first to suggest that manipulations of populations on the breeding grounds may slow the Burrowing Owl decline in a target area. In light of the rapid and ubiquitous erosion of Canada's Burrowing Owl population (Wellicome and Haug 1995), and the recent extirpation of the species from the province of Manitoba (K.D. De Smet, pers. comm.), we feel it important to continue productivity-enhancement experiments. Such experiments will provide direction for future research and conservation initiatives, both on and off the breeding grounds, by helping to determine whether the decline is linked ultimately to decreased productivity or to increased mortality.

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