Observations on the Breeding Ecology of Burrowing Owls in Saskatchewan

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ABSTRACT

Observations regarding breeding biology of burrowing owls (*Athene cunicularia*) were collected on 98 breeding pairs during 1982 and 1983. Pairs of owls were first observed on the study area in late April with clutch initiation beginning in mid-May. Overall nest success averaged 59 percent with 2.6 young fledged per nest attempt. Pairs nesting on tame pasture had a higher nest success and a greater number of young fledged per nest attempt. It was believed that predation pressure was greater for those pairs nesting on native pasture, which caused more nest failures and higher nestling mortality.

Vehicle collision accounted for 37 percent of the known mortality. Predation accounted for 41 percent, although it can be assumed that most victims of predation were never recovered. Loss of breeding habitat and lack of burrow availability is believed to represent major threats to burrowing owl populations. Organochlorides recovered from owl carcasses included DDT, DDD, DDE and heptachlor epoxide. Toxic chemicals represent a possible unknown cause of breeding failure or mortality.

Food habits were determined from 178 pellets. Overall, arthropods comprised 93 percent and vertebrates 7 percent of total numbers of prey items identified. Small mammals dominated the prey items utilized in May and early June with grasshoppers (Acrididae) being taken during July and August. Problems inherent in food habit studies are discussed.

Home range, activity patterns and foraging habitat utilization was determined with the aid of radio-telemetry. Six adult male owls were radio-marked and monitored during the peak foraging periods. Owls selected grass/forb areas more often than other habitat types for foraging. Crop and native pasture were avoided in comparison to their occurrence within the home ranges. Average home range size was 2.41 km^2 and ranged from 0.14 to 4.81 km^2. Activity patterns were monitored and it was determined that peak foraging hours occurred with long distance flights between 2000 and 0630 hours.

Management implications and recommendations are discussed.

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1.0 INTRODUCTION

The burrowing owl (Athene cunicularia) is presently designated as a threatened species by the Committee on the Status of Endangered Wildlife in Canada (Wedgwood 1978). Although population levels may have been higher in the past, it apparently has never been a very common component of the prairie fauna (Wedgwood 1978). Current data suggest a progressive decline in numbers of burrowings owls in Saskatchewan although the causes remain to be determined conclusively.

This detection of population decreases, and the consequent assignment of this species to threatened status, has provided stimulus to further research regarding potential limiting factors to burrowing owl reproduction and survival. The great majority of intensive burrowing owl research in the past has been conducted in the United States, especially in the southwestern states. Very little work has been done in Saskatchewan, the major breeding range of burrowing owls in Canada, other than preliminary census and productivity surveys (Wedgwood 1976, 1978). In order to design and implement conservation and management programs for this species, a thorough understanding of its breeding biology in the prairie provinces of Canada is necessary.

Little information has been collected regarding home range, movements and activity patterns of burrowing owls. Although some information is available concerning territory sizes of breeding pairs based on visual observations (Thomsen 1971, Butts 1971, Martin 1973a), essentially no quantitative data exist to document the home ranges of breeding pairs.

This information may prove to be a valuable management tool with respect to possible future preservation of existing breeding habitat or acquisition of lands for potential restocking programs. Similarly, little information is available concerning movements of burrowing owls within their home ranges during the breeding season, particularly with respect to habitat utilization. Again, this information may prove valuable as a management tool in the assessment of habitat requirements for the species when breeding habitat preservation or restocking programs are contemplated. Movement information, in conjunction with data regarding daily activity patterns, may also provide insight into possible limiting factors, particularly sources of mortality.

Little information is available regarding the breeding biology of Saskatchewan burrowing owls. Little quantitative data exist to document mortality factors, food habits and reproductive output - all necessary information for management of this species.

This study was designed to address the data deficiencies described above. It is separated into two sections; the first describes the nesting ecology and food habits and the second focuses upon home range, movements and activity patterns of the owls in Saskatchewan during the breeding season.

2.0 STUDY AREA

An extensive study area, portions of which were searched for burrowing owl nest sites, was located south of Saskatoon (Figure 2.1). Approximate boundaries were Highway 11 on the east, Highway 7 on the north, Highway 15 on the south and a line between the towns of Harris and Milden on the west. This area corresponds approximately to 51^{o} 30' to 52^{o} N. Lat. and 106^{o} 30' to 107^{o} 30' W. Long.

This area is part of the Saskatchewan Rivers Plain and is comprised of undulating lacustrine, fluvial, aeolian and till (moraine) lands (Hart and Hunt 1981). Elevation ranges from 490 to 640 m above sea level. Chernozemic dark brown soils predominate throughout the area with some Solonetzic and Regosolic soils, both poorly developed, associated with aeolian deposits in the vicinity of the South Saskatchewan River (Richards and Fung 1969).

Native vegetation includes grassland types of the Mixed Prairie Grassland association. The grass and forb species included in this area are listed in Appendix A. The native grassland areas are restricted to uncultivated areas primarily associated with stoney soils, excessive slopes and/or poor soil moisture. An outlier of the aspen grove/sandhill complex is located adjacent to the South Saskatchewan River. Trembling aspen (Populus tremuloides) is the most abundant tree species, with balsam popular (Populus balsamifera), paper birch (Betula papyrifera), Manitoba maple (Acer negundo), western cottonwood (Populus deltoides) and green ash (Fraxinus

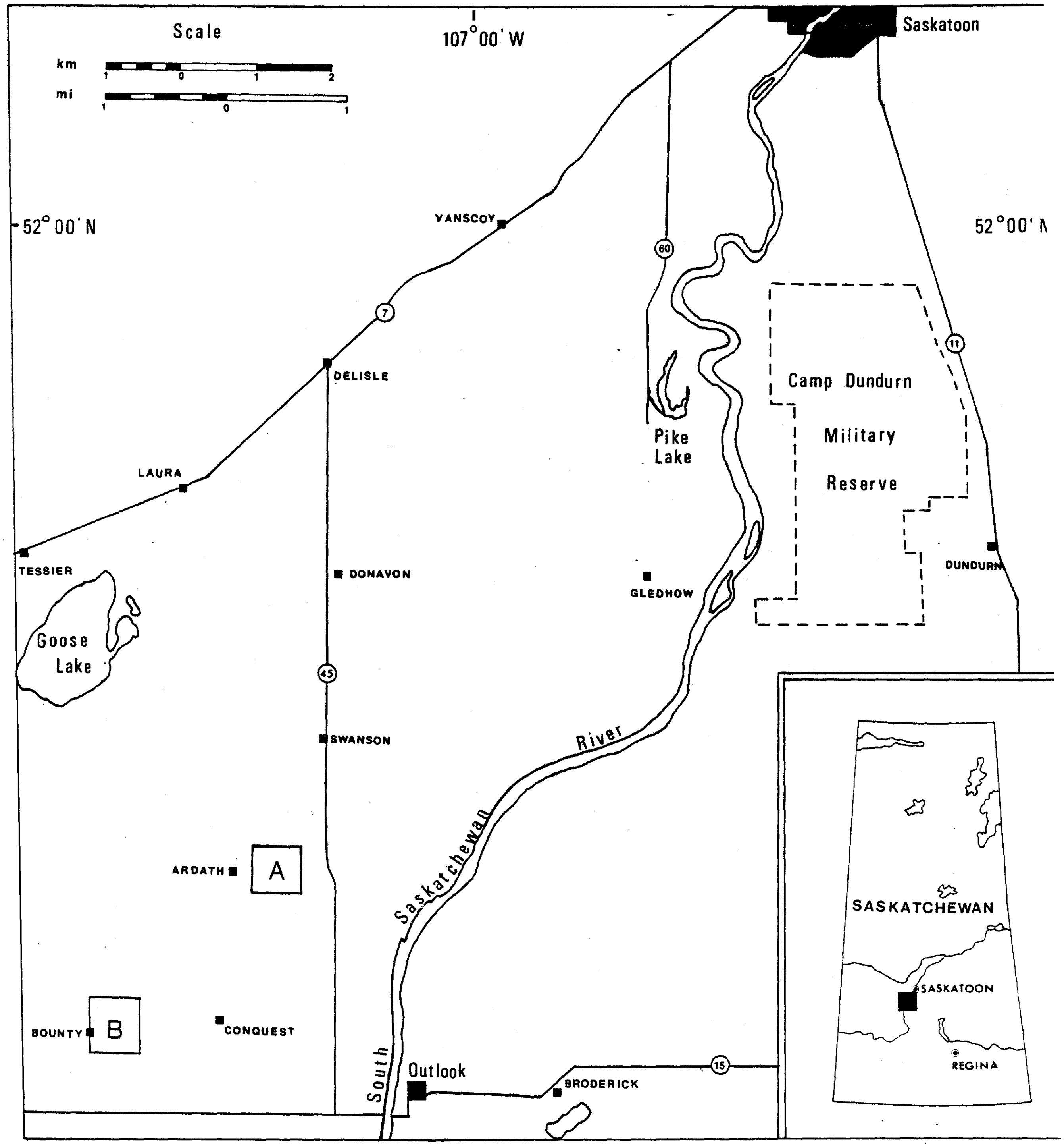


Figure 2.1. Area searched for burrowing owl nest sites, 1982 and 1983. Study Areas A and B, utilized for telemetry investigations, are indicated in the southwest corner.

pennsylvanica) occurring primarily along the South Saskatchewan River. Intensive agriculture in the form of cereal grains occurs throughout the area. Exceptions are sandy aeolian or saline areas which support native vegetation and are used for pasture.

This area experiences a semi-arid climate with an average annual precipitation between 30 and 40 cm. Mean July daily temperature is 18^{o} C (65^{o} F) with approximately 100 frost-free days (Richards and Fung 1969).

Study Area A was centered upon a 0.32 km^2 (80 acres) parcel of tame pasture near Ardath, Saskatchewan. Study Area B was centered upon a 0.64 km^2 (160 acres) parcel of native pasture near Bounty, Saskatchewan. The land surrounding both study areas was a mixture of summerfallow, cereal crops and native pasture. More detailed descriptions of the cover types and vegetation within these two intensive study areas are provided in Appendix A.

3.0 BURROWING OWL BREEDING BIOLOGY IN SASKATCHEWAN

3.1 Introduction

The burrowing owl (Athene cunicularia) is considered a rare breeding species of the Canadian prairies which represents the northern periphery of its North American range. It is presently classified as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in view of an apparent decline in numbers to an estimated 2000 breeding pairs in 1977 (Wedgwood 1978).

Intensive biological studies, conducted in the United States, have focused upon food habits and breeding biology (Grant 1965, Best 1969, Columbe 1971, Thomsen 1971, Butts 1973, Martin 1973, Ross 1974, Green 1983). Much less information is available for Canadian populations including Saskatchewan which supports the majority of breeding burrowing owls in Canada.

In conjunction with the investigations of home range and movements, information regarding aspects of breeding biology was obtained. This information is presented here to more fully understand burrowing owl breeding biology in Saskatchewan, to assess the limiting factors and to provide comparisons with other populations.

3.2 Methods and definitions

Field work was conducted from June to August 1981, and from May to October in both 1982 and 1983. Active nest sites were located by visiting previously known breeding areas recorded in Canadian Wildlife Service (CWS) files for a previous study (Wedgwood 1978). Additional information gathered by CWS and responses of local landowners to newspaper ads and poster displays were also utilized. Other nest sites were located by visually checking and/or broadcasting taperecorded primary calls (Martin 1973a) in areas which appeared to be adequate burrowing owl habitat (Zarn 1974, Wedgwood 1978). Each nest site was then systematically searched on foot to count breeding pairs and locate their nest burrows. For the purposes of this study, the definition of nest site followed Wedgwood (1978), with land bounded by fences and/or roads considered as discrete nest sites. For example, if two pairs of burrowing owls nested in an area of native pasture with a road and/or fence located between them, two nest sites would be involved. A nest site with more than three nesting pairs of burrowing owls was considered to be a colony (Wedgwood 1978).

Searches for nest sites were not designed to provide a complete census of the entire study area. Therefore, no attempt was made to calculate density estimates for this area.

Three of the 47 nest sites active between 1981 and 1983 were chosen as major study areas for telemetry studies (Study Areas A and B) and a hacking program (unpublished data). These three nest sites, involving

16 nesting pairs, provided the majority of nesting biology information and were checked daily. The other nest sites were checked biweekly to determine the progress of nesting pairs. Diurnal observations were made from a vehicle and radio-telemetry was utilized to investigate nocturnal activity.

A census route, using tape-recorded calls, was conducted twice a week from 1 May to 15 June each year (unpublished data). This provided information regarding dates of arrivals and nesting phenology of the burrowing owls. Nesting phenology was also determined by backdating from estimated ages of trapped young owls. These age estimates were determined by comparison with growth rate data collected by Landry (1979) and from young owls hatched and raised during this study (unpublished data). Fledging, or first flight of young owls from nest burrows, and dispersal of families, was determined through visual and telemetry observations.

A nest attempt was defined as any pair of burrowing owls which had selected a burrow and appeared to initiate egg-laying. A nest success was a nesting pair which raised at least one young owl to fledging. Nest failures were classified into three groups: 1) the eggs or young were destroyed by a mammalian predator; 2) one or both of the adults were killed and the nest abandoned; or 3) the pair deserted the nest for unknown reasons. Non-breeders were single owls which did not nest. No information was gathered regarding clutch size other than that obtained from the excavation of two active nest burrows. It was not possible to obtain data regarding hatching success. Productivity estimates (number of young owls fledged) were based upon the maximum number of emerging or trapped young.

Avian and mammalian predators were recorded near nest sites. Knowledge of resident predators and predator sign at carcasses or nest sites aided in determining causes of adult and young mortality and nest failures.

Attempts were made to trap, band and colour-mark all adult and young owls for individual recognition. Adult owls were captured using padded steel leg-hold traps (#0) buried at the burrow entrance. Young owls were captured using net enclosures over the nest burrow and one-way doors inserted in the burrow entrance. Owls were weighed and measured, sexed by presence or absence of brood patch (adults) (Howell 1964, Martin 1973b), and banded with USFWS aluminum leg-bands and from one to three coloured leg jesses (F. Hamerstrom, pers. comm.). Advertisements were placed in selected journals and publications, and bulletins were sent to many U.S. state and federal wildlife agencies and conservation groups requesting information on colour-marked birds observed during migration and on wintering areas.

Food habits were determined by collection and analysis of pellets regurgitated around the nest burrows and perches. These were collected every 10-15 days from nesting pairs at the two telemetry study sites. Pellets were dried, broken apart and the number and type of prey items determined (United States Fish and Wildlife Service 1942, Marti 1974). Skulls, dentition patterns and fur were used for identification of mammalian remains. Insect remains were identified using jaws, heads, legs and elytra. Prey items were compared with a personal reference collection and the University of Saskatchewan collection. Attempts were made to identify mammals to genus and insects to family. Frequency of occurrence of a particular prey item was calculated for all food items. Percent volume of prey items was visually estimated for each pellet analyzed.

Small mammal and grasshopper indices for 1982 and 1983 were determined for the two telemetry study sites (see Section 4.2 for details). Additional information was obtained from visual observation of hunting owls and examination of prey remains within and at the entrance of nest burrows.

Ten owls, one owl egg and seven small mammal samples were analyzed by the Animal Pathology Laboratory, Saskatoon, for organochloride and organophosphate residues. The owls were victims of vehicle collisions, inclement weather or predation on the study area. The small mammals were obtained from trap lines, and the egg was found after a mammalian predator had entered a nest burrow. All samples were kept frozen until they could be homogenized. They were then refrozen until submission for analysis. All samples were analyzed for malathion, aldrin, dieldrin, BHC, chlordane and oxychlordane, chlorpyrifos, coumaphos, crufomate, DDT and metabolites, dicofol, dioxathion endosulfan, ethion, ethoxyquin, heptachlor epoxide, lindane, methoxychlor, ronnel, tetrachlorvinphos, toxaphene and PCB. In addition, samples collected during 1983 were analyzed for vapona, phosdrin, thimet, dimethoate, diazinon, methyl parathion, malathion, fenthion, parathion, dursban, ruelene, gardona, methyl trithion, trithion, imidon, guthion, co-ral and dioxathion.

Vegetation in the immediate vicinity of nest burrows, and the surrounding nest site, was recorded. Changes in this vegetation and subsequent effects upon behaviour were also noted.

All statistical tests of significance utilized the five percent level of confidence.

3.3 Results and discussion

3.3.1 Phenology

A summary of phenological events is presented in Table 3.1. Owls were first observed on the study area in late April, with the greatest influx of owls occurring the first week of May. Except for a few unpaired males, owls arrived on the nesting sites already paired. Burrowing owls in Colorado (Bailey and Neidrach 1965), Minnesota (Grant 1965) and New Mexico (Martin 1973b) were also paired upon their arrival at the nesting sites.

Although most owls had paired on the wintering areas, or along the spring migration route, male owls still exhibited some courtship displays. These consisted of the primary call (Thomsen 1971, Martin 1973b) and both the "White and Tall" stance and mutual preening (Butts 1973). Courtship flights as described by Eckert (1974) and Thompson (1971) were never observed during this study. The primary call was mainly given by unmated male owls, and appeared to be important in pair formation. However, this calling behaviour in male owls with mates could be elicited by broadcasting tape-recorded primary calls. This was particularly effective during the beginning of the breeding season in May. In this case, it appeared this calling behavior represented territorial defense. A similar response was observed by Martin (1973) in New Mexico. In six cases physical contact was invoked between neighbouring pairs of owls in this study through the use of tape-recorded calls. Selection of nest burrows, as described

Table 3.1. The breeding phenology of burrowing owls in Saskatchewan, 1982 and 1983.

Event	1982	1983
Owls first observed in study area	29 April	28 April
Major arrivals	1-7 May	29 April-5 May
Major hatch period*	11-17 June	14-20 June
Range	31 May-6 July	8 June-2 July
Nestlings first observed at burrow entrance	20 June	29 June
Families began dispersing from nest sites	8 August	21 July
Owls last observed in study area	23 September	21 October

* Determined by backdating from approximate ages of trapped young.

by Butts (1973), was never recorded. In almost all cases pairs of owls utilized the burrows where they were first observed.

Egg-laying and incubation began during the third and fourth week of May and only female owls were observed to develop a brood patch and incubate. The male owls were seldom observed entering the burrow during this period, and did not appear to participate in incubation as suggested by Ross (1974) and Eckert (1974). Butts (1973) excavated nest burrows and found eggs in different stages of development. Landry (1979) utilized artificial burrows (Collins and Landry 1977) and found eggs hatched asynchronously over a four to five day period. These examples suggest incubation begins with the first egg laid. During this study, two nest burrows were excavated on May 20 and May 24, 1983, prior to cultivation of the nest sites. These nests contained five and nine eggs, all cold. The eggs were candled and it was found that none of the eggs in either clutch had been incubated, since no indications of embryonic development were apparent. All eggs hatched synchronously at 23 days. This suggested incubation for these clutches had not begun with the first egg laid. Henny and Blus (1981) also found cold, complete clutches during a study in Oregon.

The two clutches obtained during this study were artificially incubated at 37.5°C. and most pipping occurred at 23 days (range 22 to 24) (unpublished data). The only known literature reference regarding a three-week incubation period is Bendire (1892). It is generally believed incubation spans about four weeks (Zarn 1974, Henny and Blus 1981). However, the laboratory results of this study and the field results from the literature may not be suitable for comparison.

Peak hatch dates were estimated to be 14 June, 1982, and 17 June, 1983, with 50 percent of the clutches hatching from 11 to 17 June, and 14 to 20 June, in 1982 and 1983, respectively. Latest hatch dates were estimated to be 6 July, 1982, and 2 July, 1983. In 1982, two pairs of owls appeared to attempt to renest, but both pairs disappeared before any young owls were observed. Wedgwood (1976) discussed a possible renesting attempt in Saskatchewan with a downy young observed on 9 August.

Downy young were first observed at burrow entrances in the third and fourth week of June. Young owls were observed performing short practice flights during mid-July and making strong flights from nest burrows during the third week of July. As flight skills improved, young owls began leaving the immediate burrow areas and joining the adult owls on foraging flights at dusk. In these instances the young owls could often be heard begging for food during darkness at locations distant from the nesting sites.

Family units began dispersing from nesting sites as the young owls became less dependent at the end of July and early August. It also appeared that individual young owls dispersed from nest sites, but this could not be confirmed because mortality may have been a factor. Gleason (1978) concluded dispersal may be a response to depleted prey populations in immediate nest site areas. Wedgwood (1976) reported 8 October to be the latest a burrowing owl had been reported in the

Saskatoon area. During this study an owl was observed on 21 October, 1983, in the vicinity of Grandora, Saskatchewan.

3.3.2 Nest site and burrow characteristics

Zarn (1974), Wedgwood (1978) and Marks and Ball (1983) summarize the preferred nesting habitat for burrowing owls. All agree the major criteria essential for nesting habitat are openness of site, availability of nest burrows and short grass. Burrowing owls in Oregon (Green 1983) were also found to select habitats with high perches, thought to be important in both predator/prey detection and heat loss.

During this study a total of 47 active nest sites was found although not all were occupied each year. All nest sites exhibited the nesting habitat criteria listed above with three exceptions. One nest burrow was found on a road allowance and another in a small (approximately 100 m^2) patch of uncultivated land, both with grass cover approximately 0.75 m high. The third exception was a nest burrow found on a public fairgrounds which, although seldom frequented by humans, was surrounded by small sheds and bleachers. In all of these cases use of the site appeared to be due to burrow availability.

Sixty percent of the nest sites were found on tame pasture and 33 percent on native pasture (see Appendix A for habitat descriptions). According to Wedgwood (1976), only two out of 45 families nested on tame pasture during a survey of central Saskatchewan.

Six colonies of burrowing owls were located, with the largest containing six nesting pairs of owls. However, the majority of nest sites contained one or two nesting pairs, as indicated in the following:

No. of pairs per site	1	2	3	4	5	6
1982	17	5	3	3	2	1
1983	4	6	7	0	1	0

The mean nearest-neighbour distance at nest sites with two or more nesting pairs was 160 m (range 53-452 m). This was comparable to the mean nearest neighbour distance of 166 m at a nesting colony of 15 pairs in New Mexico (Martin 1973). Extreme nearest neighbour distances noted in the literature include an average of 900 m in Idaho (Gleason 1978) and less than 15 yards (14 m) between nest burrows in a colony in Texas (Ross 1974).

Burrowing owls in this study primarily used burrows excavated by badgers (Taxidea taxus) although a few nest burrows were modified Richardson's ground squirrel (Spermophilus richardsonii) burrows. There was no evidence to suggest the owls excavated their own burrows. However, Walker (1974) observed a pair of burrowing owls dig their own burrow in captivity. During this study, renovation and maintenance of burrows was often seen during courtship and nesting.

All nest burrows, with one exception, were lined with shredded horse or cow dung. Butts (1973) believed these dung accumulations may have prevented water runoff from entering the nest burrow. Martin (1973) believed dung was used to mask the scent of the nest burrow. Green (1983) found a significant decrease in badger predation when dung was present as nesting material. On several occasions I observed adult owls carrying and spreading cow dung around nest burrows immediately after my visits for pellet collections. The significance of this behaviour was not readily apparent.

In 1983 two active nest burrows were excavated and examined. The internal dimensions of both burrow tunnels were approximately 13 by 18 cm. Tunnels terminated at the nest chambers which were approximately 17 by 25 cm, and 75 cm below the ground surface. The length of the burrow tunnels were 275 cm and 220 cm, with 2 turns incorporated in each. The nest chambers were lined with 7 to 8 cm of shredded cow dung. Nest burrows of burrowing owls exhibit no specific characteristics and can be many different shapes and sizes (Butts 1973).

3.3.3 Nesting production

Information regarding burrowing owl production was obtained from 61 pairs of owls in 1982 and 41 pairs in 1983. Field work in 1981 was of a preliminary nature, and not all the productivity parameters were obtained. Table 3.2 summarizes the nest success and productivity for 1981 to 1983.

Table 3.2. Nest success and productivity of burrowing owls in Saskatchewan, 1981-1983.

Parameter	1981	1982 (%)	1983 (%)	1982 and 1983 combined (%)
No. of nest attempts	--	61	41	102
No. of successful nests	41	39 (64%)	21 (51%)	60 (59%)
No. of young fledged	191	169	99	268
No. of young fledged/ successful nest	4.7	4.3	4.7	4.5
No. of young fledged/ nest attempt	--	2.8	2.4	2.6

Numbers of young produced per successful nest and nest attempts were not significantly different among the three years of this study. However, 33 percent fewer breeding pairs returned to previously known nest sites in 1983 than in 1982. Whether this was due to a reduction in the regional breeding population in 1983, or whether this represents a shift in nesting distribution as observed by Rich (1984) in Idaho was unknown. The proportion of nesting attempts which were successful was also lower in 1983 (51 percent) compared to 1982 (64 percent).

In 1982, 39 nest attempts (64 percent) produced at least one young owl to fledging. Of the 22 nest failures, 59 percent showed evidence of avian or mammalian predation on eggs or adults. Causes of the remaining nest failures were unknown. In 1983, 21 nest attempts (51 percent) produced at least one young owl to fledging (age at first flight). Of the 20 nest failures, 40 percent were believed due to mammalian predation on eggs or adults. Except for the loss of two clutches due to cultivation, the causes of the other failures were unknown. In both years, badgers and weasels (Mustela frenata) were believed to be the major predators on eggs and young owls and were often seen hunting in the vicinity of active nest sites.

Reproductive output of successful burrowing owl nests in Saskatchewan appears to be comparable to that reported in other regions (Table 3.3). However, in this study the inclusion of all nest attempts, regardless of outcome, reduced the reproductive output considerably. Several other studies did not include the productivity

Table 3.3. Comparison of burrowing owl production between studies.

	Haug 1985		Thomsen* 1971		Butts 1971	Martin 1973	Ross 1974	Landry 1979		Green 1983		Grant 1965	Wedgwood 1976	Gleason 1978	Konrad and Gilmer
	'82	'83	'65	'66	'70	'70		'74	'75	'80	'81	'63	'75	'76-'77	78
No. of pairs attempting to nest (nest attempt)	61	41	9	15	250	15	56	9	23	63	76	-	-	-	-
% Successful	64	51	89	33	79	100	95	78	70	57	50	-	-	-	-
No. young fledged/ successful nest	4.3	4.7	4.1	4.8	4.7	4.9	3.8	4.8	4.8	-	-	3.8	4.6	3.5	4.0
No. young fledged/ nest attempt	2.8	2.4	3.6	1.6	3.7	4.9	3.6	3.8	3.3	-	-	-	-	-	-

* Known nestling mortality subtracted from total young produced before calculating.

based on all nest attempts, considered to be one of the most important indices of reproductive performance (Olendorf 1973). Without this information, meaningful comparisons and conclusions regarding reproductive performance in Saskatchewan is difficult. However, assuming an accurate determination of nest failures in the limited studies available, it is evident that recruitment in Saskatchewan is low. Only Thomsen (1971) reported fewer numbers of young fledged per pair during 1966 in California.

Production of young owls between years was very similar (Table 3.2). However, there was a significant difference in production between nesting habitats (Table 3.4). There was a greater number of young produced per successful nest ($t=5.5$, $df=58$, $p < .01$) and per nest attempt ($t=4.6$, $df=100$, $p < .01$) on tame pasture than on native pasture. There was also a greater nesting success for breeding pairs using tame pasture (61 percent) compared to breeding pairs using native pasture (54 percent).

There are two possible explanations for this observed difference in production. Predation resulting in nest failures and brood reduction appeared to have been greater on native pasture. This habitat type, although not common, often occurred in blocks greater than a 0.25 mi^2 of land (.64 km^2) and consisted of soil too saline or rocky for cultivation. These areas were favoured denning sites for badgers, weasels, coyotes (_Canis latrans_) and foxes (_Vulpes vulpes_) (pers. observ.). Mammalian predators were suspected in 45 percent of all nest failures in both years. However, evidence suggested that

Table 3.4. Burrowing owl production from nest burrows found on tame and native pasture, 1982 and 1983 combined.

Parameters	Tame Pasture	Native Pasture
No. of nest attempts	74	28
No. of successful nests(%)	45 (61)	15 (54)
No. of young fledged/ successful nest	5.0	2.9
No. of young fledged/ nest attempt	3.0	1.5

mammalian predators caused 77 percent of the nest failures occurring on native pasture as compared to only 31 percent on tame pasture. Although never observed entering nest burrows, badgers and weasels were often seen hunting in native pasture near nest burrows of Gleason (1973) and Columbe (1971) both witnessed badgers enter nest burrows in Idaho and California, respectively, and Green (1983) found that badgers accounted for 18 out of 20 (90 percent) nests lost to predation in Oregon.

Difference in food availability may also have been a factor in the observed difference in production. Gleason (1973) found a positive correlation between rodents in the diet and brood size of burrowing owls in Idaho. Because of the higher number of voles available, pairs nesting within 1 km of agricultural areas produced larger broods than those nesting elsewhere. All pairs located during this study nested within 0.4 km of agricultural areas. Therefore, there was no obvious difference in availability of cereal crops for foraging to pairs in tame or native pasture if indeed small mammal densities were greater in these areas. However, interspecific competition could have been a factor if mammalian predators were more abundant on native pastures, as mentioned previously. Competition between burrowing owls and these predators could have caused a reduction in brood size and an increase in nest desertions. In Oregon, Green (1983) speculated that intraspecific competition may have caused a significant nest desertion rate for pairs of burrowing owls nesting less than 109 m apart. No observations were made during this study to indicate that intraspecific competition was a factor limiting production in

Saskatchewan.

During this study only four single nonbreeding adult owls were observed on the study area. From their behavioural response to tape-recorded calls it was believed they were all male owls. Thomsen (1971) also noted a surplus of male owls on her study area in California. Wedgwood (1976) noted nine single owls during inspection of 41 nest sites in central Saskatchewan; the sex of these owls was unknown.

There was a situation which suggested a fifth single owl in this study was involved in a polygamous relationship with another pair of owls. A single owl was observed at a nest burrow 110 m from a nest burrow of a breeding pair. Based upon the behaviour of this owl, and the large brood patch noted when it was trapped, this owl was identified as a female. This female and the female of the breeding pair were both banded and colour-marked. Although the male owl was never observed feeding the single female owl, it was flushed from the latter's burrow at least five times. Freshly killed deer mice (Peromyscus spp.), partially eaten, were found twice at the burrow mouth, after observing the male in the area. The single female was last observed on the 26 June, 1982, and on 3 July, during inspection of her burrow, it was determined this owl had deserted. The original breeding pair successfully raised five young owls to fledging. Newton (1979) discussed documented cases of polygamy in different species of hawks but no references to owls have been found.

3.3.4 Limiting factors

Breeding season mortality

Attempts were made to determine the cause of mortality of all burrowing owl remains located (Table 3.5). Of the 27 fatalities recorded in 1982 and 1983 the major cause of death was collisions with vehicles (37 percent). In 1981 at least 25 percent of the 20 young owls produced at a colony of five breeding pairs, bordered by a gravel road, were killed by vehicles. It appeared that the loss of burrowing owls to vehicle collisions was a significant mortality factor. Butts (1973) found 33 percent of known mortality resulted from roadway fatalities in Oklahoma. Wedgwood (1976) recorded 40 percent decrease in a colony bordering a road in Saskatchewan and believed vehicle collisions were the major cause.

Mammalian and avian predation accounted for 16 percent and 15 percent, respectively, of known mortality. Badgers, weasels and red foxes were suspected as causes of nest failures and death of fledglings and adult owls. Swainson's hawks (Buteo swainsoni) were the most frequently observed raptor in the vicinity of nest sites. A prairie falcon (Falco mexicanus) was observed capturing an adult burrowing owl near its nest burrow, but this falcon dropped the owl when it was surprised by my presence. Webster (1944) reported burrowing owls as the prey of prairie falcons in Colorado and Wedgwood (1978) noted predation by Swainson's hawks in Saskatchewan.

Table 3.5. Suspected causes of mortality of owls found dead on the study area, 1982 and 1983.

Causes of Mortality	Fledged Young	Adults
Mammalian predator	5	2
Avian predator	1	3
Road kills	8	2
Weather	3	1
Unknown	2	0
Total	19	8

Severe weather has been reported to adversely affect owls. During this study a sudden hail storm in July 1982 killed one adult and three young owls from the same family. Severe thunderstorms have been blamed for drowning of young burrowing owls in Saskatchewan (Wedgwood 1978).

The number of known mortalities account for seven percent of the fledging population, and eight percent of the adult population during the breeding season. This mortality rate for fledgling owls in Saskatchewan is similar to a recorded nine percent rate in California (Thomsen 1971), 11 percent in Oklahoma (Butts 1973) and 15 percent in Idaho (Gleason 1978). However, this must be considered a minumum estimate as not all mortalities were detected. It can be assumed that most victims of predation were never recovered.

Loss of breeding habitat

Burrowing owl sites, listed by J. A. Wedgwood (1978) and incorporated in his report for the Committee on the Status of Wildlife in Canada and located within the boundaries stated previously, were visited in June-August, 1981. Of the 53 sites visited, land use changes, primarily conversion to cropland, had occurred on 23 percent of them. During 1982 and 1983, another five sites were lost to cultivation, two resulting in nest failures by the breeding pairs. This was a 11 percent loss of known nesting habitat over a two year period.

Zarn (1974) and Wedgwood (1978) consider loss of nesting habitat through cultivation, urban development and road building to be a serious threat to burrowing owl populations.

Burrow availability

In 1981 burrow availability was assessed at 19 nesting sites with 27 families present. There was an average of six available burrows within a 30 m radius of the nest burrow (range 1-13 m). An average of four burrows was used by the family groups after the young began moving in the vicinity of the nesting burrow (range 1-8). It would appear that burrow availability was not a problem in this area. However, any form of destruction of burrowing mammals could have an adverse effect on burrowing owl numbers. In Oklahoma, the removal of prairie dogs by poisoning allowed deterioration of their burrows, making them unsuitable for owls after one year (Butts 1973). In California, agricultural improvements resulting in a reduction in nest burrows was found to reduce burrowing owl numbers (Columbe 1971).

Environmental poisons

Organochloride residues detected in owl and small mammal tissue samples from the study area included DDT, DDD, DDE, heptachlor epoxide and lindane (Table 3.6). Heptachlor epoxide and DDE were detected in one egg sample and either DDT, DDD or DDE was detected in three owl tissue samples with all three organochlorides present in a fourth sample (four out of ten, 40%). Only one mouse tissue sample showed residues of organochlorides; lindane was present in a small amount.

Table 3.6. Pesticide residues (ppm wet weight) in burrowing owl and small mammal tissue samples, 1982 and 1983.

Year	Sample Tissue	Organophosphates	Organochlorides
1982	Burrowing owl	N.D*	N.D.
1982	Burrowing owl	N.D.	DDT 0.023
			DDE 0.120
			DDD 0.037
1983	Burrowing owl	N.D.	DDD 0.023
1983	Burrowing owl	N.D.	N.D.
1983	Burrowing owl	N.D.	DDE 0.039
1983	Burrowing owl	N.D.	N.D.
1983	Burrowing owl	N.D.	N.D.
1983	Burrowing owl	N.D.	N.D.
1983	Burrowing owl	N.D.	DDE 0.401
1983	Burrowing owl	N.D.	N.D.
1983	Burrowing owl egg	N.D.	HCE 0.025
			DDE 0.073
1983	*Peromyscus maniculatus*		
1983	*Peromyscus maniculatus*	N.D.	N.D.
1983	*Peromyscus maniculatus*	N.D.	Lindane 0.039
1983	*Peromyscus maniculatus*	N.D.	N.D.
1983	*Peromyscus maniculatus*	N.D.	N.D.
1983	*Peromyscus maniculatus*	N.D.	N.D.
1983	*Peromyscus maniculatus*	N.D.	N.D.

N.D. = Not Detected

In Oregon, burrowing owl eggs were found to contain residues of heptachlor epoxide (two of six, 33%) and DDE (five of six, 83%) (Henny et al. 1984). Concentrations were considered low (range 0.16-0.19 and 0.11-0.66 ppm, respectively) and did not appear to affect reproduction. However, any toxic residues may cause undocumented mortality or reproductive failures in birds stressed by migration, weather or predators.

3.3.5 Site fidelity and migration

A total of 214 owls were leg-banded and colour-marked in 1981-1983 to allow for individual recognition of breeding pairs on the nest sites, and to aid in delineation of migration routes and wintering areas of this population. Pair and site fidelity information from the colour-marked owls was also recorded.

Of 13 fledglings banded in 1981, one male returned in 1982 and bred successfully. Although he returned to the same nest site he utilized a different burrow.

In 1982, 112 owls were banded and colour-marked (31 adults, 81 young). Four owls, banded as adults, were observed to return in 1983, all to the same nest sites where they had been banded. In one case, a banded male owl used the same nest burrow but mated with a banded female from a different pair. One owl banded as a fledgling was found dead on a highway approximately two miles (3.2 km) north of its birthplace.

In 1983, 89 owls were banded and colour-marked (22 adults, 67 young). This study was terminated in 1983 and observations of returning owls were not obtained. No reports of banded owls during migration were received.

No attempt was made to calculate overwinter mortality rates from the banding return information. Rates calculated from these small sample sizes would be misleading and lack of reobservations may not necessarily represent mortality since owls may have returned but nested elsewhere. A study of a nonmigratory population of burrowing owls in California (Thomsen 1971) indicated mortality rates for young and adult owls to be 70 percent and 19 percent, respectively. It can be assumed that due to the stress and hazards associated with migration that mortality rates for burrowing owls in Saskatchewan may be considerably higher.

3.3.6 Feeding behaviour and food habits

Foraging methods

Many authors have noted the various foraging patterns used by burrowing owls (Columbe 1971, Martin 1971, Thomsen 1971, Butts 1973, Ross 1974). In this study owls were commonly observed utilizing four foraging methods: 1) ground hunting - the owls were observed to hop, walk and run along the ground in pursuit of insects. They frequently stopped to pick at cow dung in search of beetles; 2) perch hunting -

the owls used an elevated perch for locating prey and then flew to this prey. This was used to hunt insects and small mammals after sunset; 3) hovering - owls were observed hovering over tall, dense vegetation. It was believed this method was used to locate small mammals and it was observed only after sunset; 4) flycatching - owls were observed in aerial pursuit of insects, similar to flycatchers (Tyrannidae). This was most often observed during warm afternoons when insects were most active.

A fifth foraging method, gleaning insects, was observed only five times during this study. The owls were observed flying to tall grasses or sweet clover and plucking grasshoppers from the stalks. This occurred after sunset when the air temperature was decreasing and grasshoppers were becoming less active. The only other reference to this type of feeding behaviour was Scott (1940) who observed burrowing owls commonly gleaning grasshoppers from "shocks of oats" in Iowa.

Collins (1976) reviews food caching behaviour in many species of captive owls. Although Grant (1965), Gleason (1978) and Rich and Trentlage (1983) recorded burrowing owl food caches away from nest burrows, it was not observed during this study. Vertebrate prey items stored within the nest burrow were recorded four times. In two cases three and seven prey items were found inside burrow tunnels. Two nest burrows which were examined through excavation yielded seven and 20 prey items. Most of the prey species found had been beheaded, but otherwise remained uneaten. Ross (1974), Eckert (1974), Landry (1979), and Henny and Blus (1981) all have reported food storage, or stockpiling (Collins 1976), in the burrowing owl populations they studied. Ross (1974) cites both need, since a large number of young owls were noted where prey items were found, and availability of prey as contributing factors in Texas.

Cannibalism

Cannibalism was not directly observed during this study. However, remains of nestling burrowing owls, apparently cannibalized by siblings, were found on eight occasions in and around the mouths of nest burrows. It was not possible to determine whether they had died due to their inability to compete with stronger siblings, or if fratricide had occurred. Robinson (1954), Landry (1979) and Green (1983) all reported cases of cannibalism in the burrowing owl populations they studied. Green (1983) also reported an older brood of juvenile owls killing and cannibalizing a younger brood in captivity. Fratricide and cannibalism are considered a method of ensuring survival of the strongest young (Ingram 1959).

Food habits

An analysis of 178 pellets collected in 1982 and 1983 yielded a minimum of 1,842 prey items (Table 3.7). Arthropods comprised 93 percent of the total number of prey items with grasshoppers (Acrididae) dominating the number of arthropods identified (75 percent). *Peromyscus* spp. was the most frequent vertebrate prey consumed (25 percent) and unknown passerines comprised 21 percent of

Table 3.7. Minimum numbers of prey items detected in 178 burrowing owl pellets, 1982 and 1983.

Prey Item	1982 (%)	1983 (%)	Total (%)
No. of pellets	134	44	178
Microtus spp.	18	6	24
Peromyscus spp.	25	6	31
Perognathus fasciatus	3		3
Onychomys leucogaster	1		1
Mus musculus	3		3
Spermophilus spp.	1	1	2
Thomomys talpoides	4		4
Unknown mammal	22	9	31
TOTAL MAMMALIAN	77 (5)	22 (6)	99 (5)
TOTAL AVIAN	13 (1)	13 (3)	26 (1)
Orthoptera			
Acrididae	1086	210	1296
Coleoptera			
Silphidae	68	22	90
Scarabidae	171	102	273
Elateridae	3		3
Unknown	40	11	51
Hymenoptera			
Formicidae	3		3
Unknown arthropods	1		1
TOTAL ARTHROPODS	1372 (94)	345 (91)	1717 (93)
TOTAL	1462	380	1842

the total vertebrate items identified.

Figure 3.1 and Table 3.8 illustrate the extent to which arthropods dominated the prey consumed during the breeding season. The frequency of occurrence of Coleoptera remained relatively stable; however, the frequency of occurrence of grasshoppers (Acrididae) increased steadily, peaking at 100 percent (Table 3.8) and almost 100 percent pellet volume (Figure 3.1) by August of both years. Many Coleoptera were crushed beyond recognition. However, some characteristics still evident suggested that Carabidae and Tenebrionidae were the major groups of Coleoptera in the unknown category.

Small mammals were the dominant prey items in May and early June. This level of use decreased during the remainder of the breeding season until late September, 1982, when their occurrence and volume in pellets increased once again. Avian remains occurred in pellets throughout the breeding season. Remains consisted of a few matted feathers and bone, precluding any chance of species identification. However, remains of horned larks (Eremophila alpestris) and chestnut-collared longspurs (Calcarius ornatus) were identified near nest burrows. Reptiles and amphibians were not detected during pellet analyses, however, remains of tiger salamanders (Ambystoma tigrinum) and toads (Bufo spp.) were observed, whole and beheaded, in the vicinity of nest burrows.

The information presented in Table 3.8 and Figure 3.1 correlates well with visual observations of prey density during the study period.

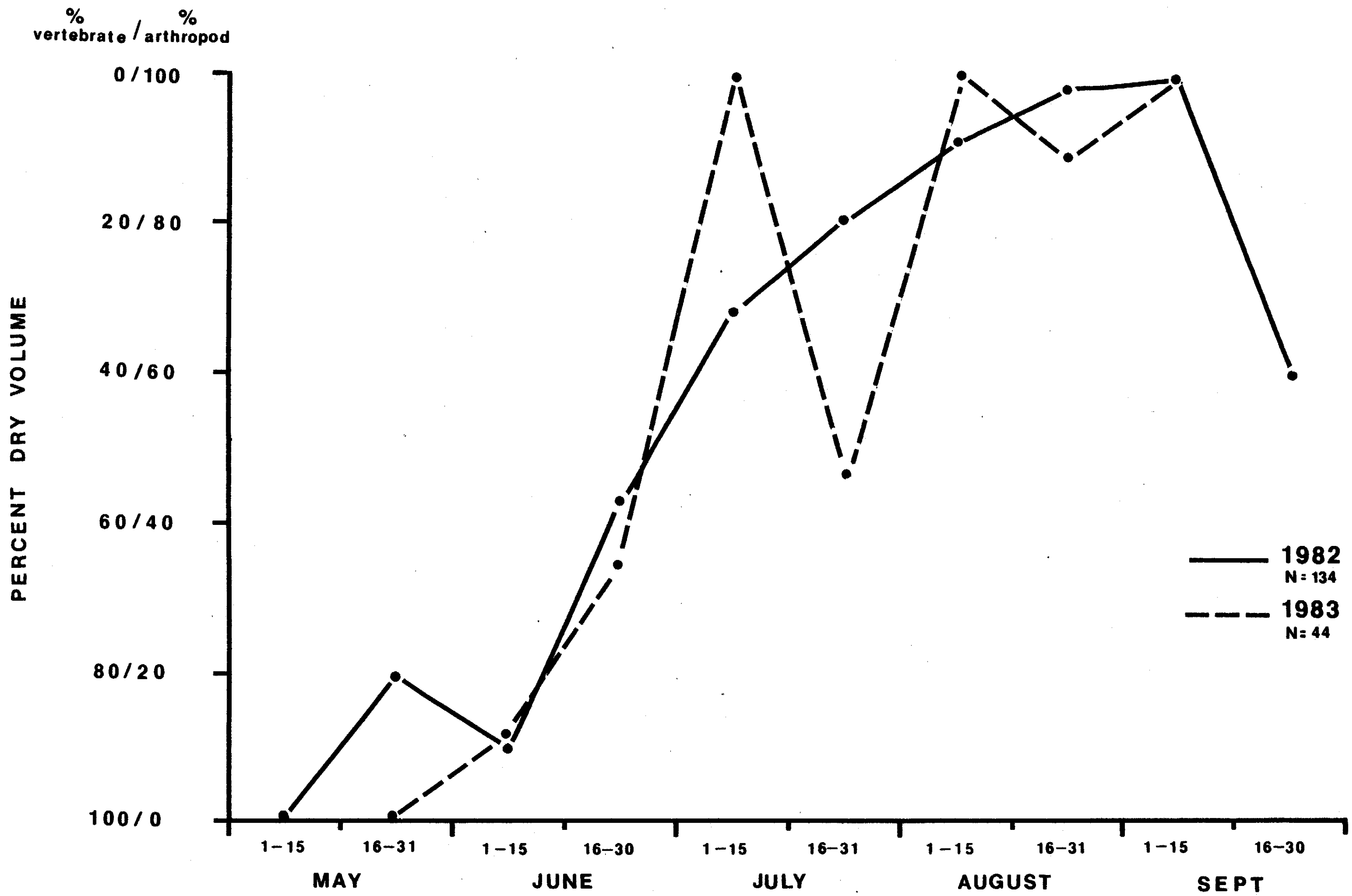


Figure 3.1. Average estimated percent dry volume of vertebrate and arthropod prey remains from 178 burrowing owl pellets, 1982 and 1983.

Table 3.8. Percent frequency of occurrence of prey remains in burrowing owl pellets, 1982 and 1983.

FOOD ITEMS	MAY		JUNE		JULY		AUGUST		SEPTEMBER		TOTALS	
	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983
No. pellets analyzed	20	3	29	14	30	6	31	16	24	5	134	44
Microtus spp.	40	33	14	28	10				13		13	11
Peromyscus spp.	55	67	21	21	3		10		4		16	11
Perognathus fasciatus			7		3						2	
Onychomys leucogaster			3								1	
Mus musculus			7		3						2	
Spermophilus spp.			3	7							1	2
Thomomys talpoides			3		7						2	
Unknown	10		31	35	20	33	7	6	13	20	16	20
TOTAL MAMMALS	90	100	79	93	43	33	16	6	29	20	54	45
TOTAL BIRDS	5	33	17	7	3	50	13	44	8	20	10	30
Orthoptera												
Acrididae	5		21	7	87	67	100	100	88	80	63	57
Coleoptera												
Silphidae	20		14	21	30	33	23	31	54	40	28	27
Scarabidae	30		24	29	7	50	6	6	8		14	18
Elateridae			10								2	
Unknown			14	43	30		13	13	4		13	18
Hymenoptera												
Formicidae			3								1	
Unknown									4		1	
TOTAL ARTHROPODS	40	0	48	71	97	100	100	100	88	100	76	84

Numbers of Coleoptera, especially dung beetles (Scarabidae) and carrion beetles (Silphidae), appeared to remain relatively constant in numbers, while numbers of grasshoppers in the vicinity of the nest sites increased steadily throughout the summer months. Small mammal trapping results were inconclusive due to small samples for each habitat type. Combined results yielded 59 Peromyscus spp. and two Microtus spp. trapped during 1900 trap nights. This suggests that Peromyscus spp. was the most abundant small mammal in the owls' home ranges and numbers appeared to remain constant throughout the breeding season.

Burrowing owls have been reported to feed on a wide variety of both arthropods and vertebrates depending upon the geographical location and corresponding prey species (Zarn 1974). Best (1969) reported a greater utilization of arthropods, predominantly Coleoptera, during May and June in New Mexico as compared to a greater use of small mammals and birds in this study. Smith and Murphy (1973) noted that silphid beetles (Silphidae) were the most common prey during late summer in Utah. A predominantly vertebrate diet was noted by Errington and Bennet (1935) and Scott (1940) in Iowa from June through August, with an increase in insects during September. The vertebrate/arthropod ratio of numbers of prey species utilized in Oregon (Green 1983) (8 percent vertebrate/92 percent arthropod) was similar to that found during this study (7 percent vertebrate/93 percent arthropod); however, prey species composition varied between studies.

Information gained from this and previously mentioned studies suggest local conditions and prey availability determine the diet of burrowing owls across western North America (Zarn 1974). Food habit data obtained from this study also support the theory that burrowing owls are opportunistic and will select the prey items most easily obtainable.

Laboratory studies of captive owls have suggested regurgitated pellets provide suitable representations of prey items consumed (Errington 1930) and are considered accurate indicators of type and number of prey species (Marti 1974). However, evidence obtained from this and other food habit studies suggest burrowing owl pellets may not be as reliable as previously thought. Of the 99 small mammal remains found in the pellets analyzed, 51 percent were skulls or jaws only. Thirty-one percent were hair and bones in varying proportions and only 18 percent of the small mammal remains contained complete body parts. Of the 20 vertebrate prey items found in the tunnel of one nest burrow, 50 percent were beheaded but otherwise untouched. Grant (1965), Thomsen (1971) and Butts (1973) have noted similar behaviour and consider burrowing owl pellets poor indicators of the number of prey items consumed. Studies which utilize biomass calculations to determine the importance of particular prey groups in burrowing owl diets should be interpreted with caution. Other problems encountered which create biases in the results of the pellet analysis are:
1) reptiles and amphibians were believed underestimated in the pellets based on remains found around the nest burrows. Thomsen (1971) also noted this in California and speculated that little skeletal material

was eaten; 2) bony material is digested by young owls causing a bias in the amount of the vertebrate prey estimated (Errington 1930); 3) the increase in percentage of arthropod remains in late summer may be partially due to the selection of the large vulnerable insects by the inexperienced young (Errington and Bennett 1935); and 4) pellets composed entirely of insect remains breakdown quickly following ejection (Butts 1973, Marti 1974) and may be underestimated.

3.4 Summary

The following aspects are apparent from this study:

1) Owls were first observed on the study area at the end of April and were last observed in mid-October. Birds arrived paired and established nest burrows and territories immediately.

2) Only the female was observed to incubate with an incubation period ranging from 22-24 days under artificial conditions. This is in contrast to a previous concept of an incubation period of 28 days.

3) Observation of two clutches suggested incubation begins after the clutch was complete although other studies have found incubation started with the first egg laid.

4) Data from 102 nesting pairs indicated an average of 4.5 young fledged per successful nest and 2.6 young fledged per nest attempt. Reproductive output was lower in Saskatchewan than areas investigated in the United States, and it was unknown if production was replacing losses. Nest failures and nestling mortality were primarily due to predation. Interspecific competition for small mammals may have been a lesser contributing factor to nest losses.

5) A total of 214 owls were banded and colourmarked. Of these, only five birds were known to return to the study area. Four of these returned to the same pasture where they were banded. No reports of banded owls observed during migration were received.

6) Owls were observed utilizing five foraging methods: ground hunting, perch hunting, hovering, flycatching and gleaning insects. Food storage within nest burrows was observed four times. Cannibalism

was never directly observed, however, remains of nestling owls, apparently cannibalized by siblings were observed around nest burrows.

7) Analysis of 178 pellets yielded a minimum of 1842 prey items. Arthropods comprised 93 percent of the total number and were utilized predominantly in middle to late summer. Small numbers of birds and small mammals were utilized consistantly throughout the breeding season. This information suggests local conditions and prey availability determine the diet of burrowing owls in this area.

8) Factors limiting recruitment to the population were investigated and included a) mortality: vehicle collisions, avian and mammalian predation and severe weather all adversely affected the survival of the owls; b) loss of breeding habitat: from 1977 to 1981, 23 percent of known nest sites as reported by Wedgwood (1978) had been converted to cropland. During this study (1982 and 1983), 11 percent of the nest sites monitored were also lost to cultivation; c) burrow availability: this does not appear to be a problem in this area. However, any form of destruction of burrowing mammals could have an adverse effect upon burrowing owl numbers; d) environmental poisons: toxic chemicals were detected at concentrations of less than 1 ppm in tissue samples and included DDT, DDD, DDE and HCE. Lindane was detected in one small mammal sample. Toxic residues may cause undocumented mortality or reproductive failures in birds stressed by migration, weather, disease, or predators.

4.0 MOVEMENTS, ACTIVITY PATTERNS AND HABITAT UTILIZATION OF BURROWING OWLS IN CENTRAL SASKATCHEWAN

4.1 Introduction

The burrowing owl is classified as a threatened species in Canada (Wedgwood 1978) because of an apparent decline of the small breeding population. Saskatchewan, which is the primary breeding range of the burrowing owl in Canada, has been subject to loss of native habitat of all types by conversion to cropland. Loss of nesting habitat has been fconsidered to be a leading cause of the apparent population decline of this species in the United States, but the causes appear to be more complex on the Canadian prairies (Wedgwood 1978).

As nesting habitat of the burrowing owl declines on the prairies, it becomes increasingly important to fully understand the habitat requirements of this species for management and preservation purposes. Several investigators (Columbe 1971, Thomsen 1971, Martin 1973, Ross 1974, Gleason 1978, Wedgwood 1976 and others) have documented various aspects of the diurnal activities of the burrowing owl during the breeding season. With the advent of radio-telemetry, a technique for monitoring nocturnal activities is now available.

This study was initiated to determine foraging habitat requirements of the burrowing owl in Saskatchewan through investigation of its movements during the breeding season. The development of a transmitter package for use on small owls was designed and implemented.

4.2 Methods and definitions

4.2.1 Trapping and marking

Field work was conducted from May to October during 1982 and 1983. Study areas used for radio-telemetry investigations were intensively searched on foot to determine the total number of nesting pairs. Attempts were made to capture and colour-mark all adult owls at these areas to identify individuals not radio-marked. Owls were captured using padded steel leg-hold traps (#0) buried at the burrow entrance. Owls were weighed, measured, sexed by presence or absence of a brood patch, banded with USFWS aluminum leg-bands and colour-marked with plastic leg jesses (design by F. Hamerstrom, pers. comm.).

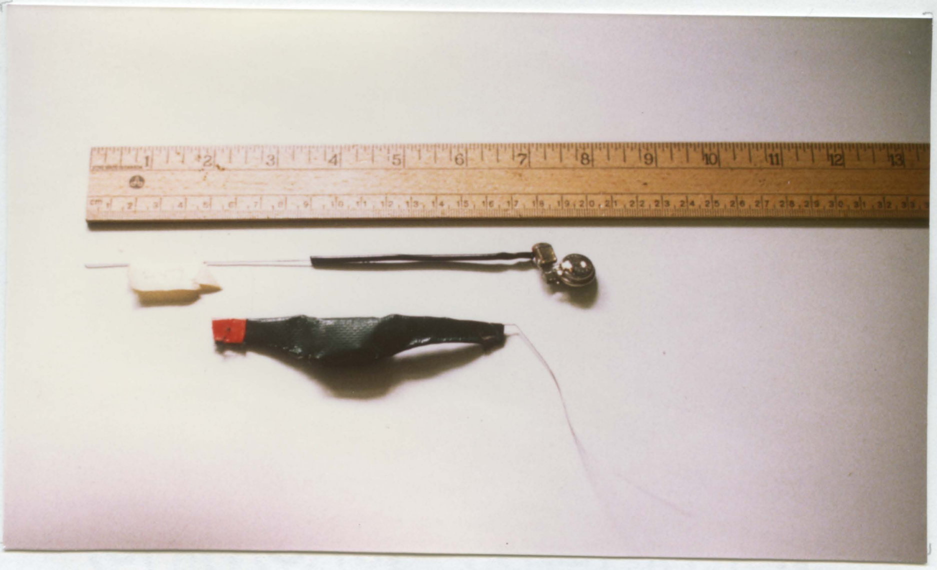
4.2.2 Telemetry equipment

A total of nine adult male owls were instrumented with radio-transmitter packages (eight to nine grams) modified from a poncho design (Amstrup 1980) used with sharp-tailed grouse (*Tympanachus phasianellus*). The poncho material was "TXN 18" vinyl-coated nylon fabric (Cooley Inc., Mississauga, Ontario) and the transmitters were "SM1" models (AVM Instrument Co., Dublin, California). A pre-tabbed mercury battery and high resilience antenna wire were soldered to the transmitter and the entire unit coated with a thin layer of dental acrylic. Owl numbers refer to the radio-transmitter each owl carried, and were retained for convenience only.

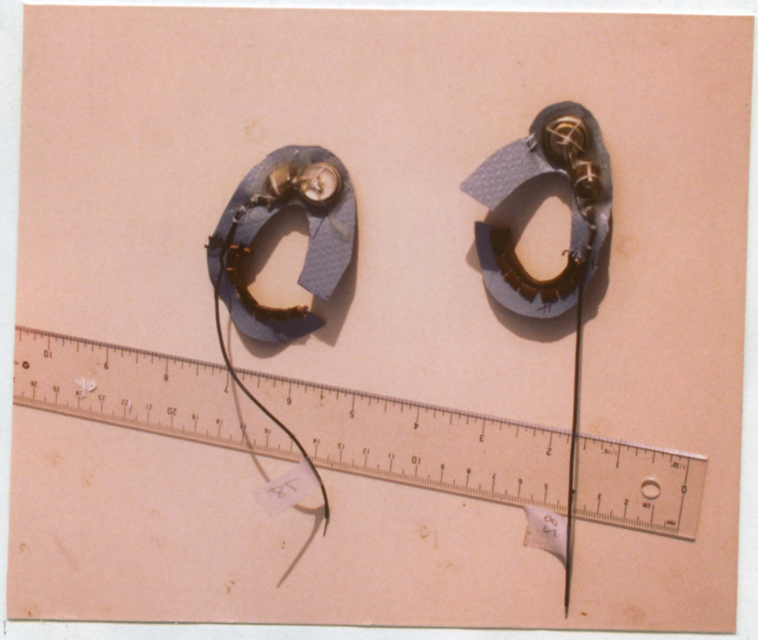
In 1982 the transmitter package was designed and worn like a collar (Plate 4.1). A 140 x 50 mm strip of fabric was cut and folded lengthwise. This was machine sewn with nylon thread from the center lengthwise tapering from 20mm wide at the center to 10mm wide at the end. When turned "inside out", all seams were inside to ensure no sharp fabric edges could contact skin or mouth parts if an owl attempted removal of the collar. This produced a snug fitting pocket which held the transmitter and battery package and was then closed by hand-sewing such that the collar tapered to a 10 mm width at both ends. The antenna was within the collar and exited from a small hole approximately 40 mm from the middle of the pocket. When the collar was fitted to the owl, both ends were riveted together, and any excess material trimmed.

In 1983 the Amstrup (1980) poncho design was copied (Plate 4.1) with two modifications: 1) a strip of soft leather overlapped, and was sewn to the upper half of the neck hole to reduce skin irritation at the main site of poncho support, and 2) the poncho was cut in two on one side to allow size adjustments. When a fit was made, the two ends were riveted together. All excess fabric was trimmed to reduce weight.

All packages were designed to "break-away" by making a second cut and resewing with cotton thread. Should attempts to retrap an owl and



1982



1983

Plate 4.1. Designs of transmitter packages used on burrowing owls, 1982 and 1983.

remove its transmitter package be unsuccessful, the cotton thread would rot and the package would fall off within a few months. In both 1982 and 1983 designs, the antenna projected perpendicular to the back of the owl which allowed for maximum range.

When the owls were handled, they assumed a "hunched" posture with the head held tightly against the shoulders. When fitting either design, it was necessary to gently pull the owl's head and straighten its neck, creating a more natural posture. Without this procedure, the collar was too large and often slipped up over the face of the owl when it attempted to remove the collar. A space of 20 - 25 mm was allowed between the collar and the owl's neck for eating and pellet regurgitation.

Under ideal conditions, with the instrumented owl at ground level, the transmitter package had a range of 1.6 km. The transmitters operated from 10 to 74 days. When signals were lost, attempts were made to retrap owls and remove collars.

A Model CE 12 receiver (Custom Electronics of Urbana, Inc) and one five-element yagi or two five-element yagis (A-S Antronics, Urbana, Illinois) mounted in null/peak configuration upon a car-top carrier were used to monitor the radio-tagged owls. Vehicle access in and around the telemetry study area allowed for over 95 percent of the bearings to be determined from a distance of 0.8 km or less. Accuracy of bearings of the total system was within two degrees at this distance.

4.2.3 Data collection

Adult male burrowing owls were monitored in 1982 and 1983, using visual and radio-tracking observations, from their appearance in the first week of May until their departure from the nesting sites in August or September. The radio-telemetry studies were conducted from 13 June to 27 August, 1982, and from 6 June to 8 July, 1983.

The attachment of the radio-transmitters to male owls was delayed until the females were in late stages of incubation to minimize the possibility of nest desertion. It was assumed that the greatest foraging activity by the males would occur after the young hatched, but while the female was still brooding. Attempts were made to monitor all radio-marked males during this time period.

During daylight hours, the transmitter signal was used to locate the owl. Visual observations were then obtained from a vehicle using 10 X 50 binoculars and a 20X spotting scope. At night, radio-marked owls were located by triangulation of signals. Using a hand compass, two bearings were taken from 0.4 km or more apart and the intersection of these bearings was plotted upon 1:20,000 scale photo map sheets. Owl locations were determined every 15 to 45 minutes depending upon the owl's activity and weather conditions. A moving owl could be detected by a change in signal strength and direction, and precautions were taken to ensure an owl was stationary before determining its position.

Weather, the relative positions of each owl to one another, and the ease of locating individual owls determined whether a single owl was monitored for the entire observation period (up to 12 hours) or alternate tracking of two or more owls was conducted. Most radio-tracking of each owl was conducted continuously throughout the period between sunset and sunrise. Attempts made to achieve the same amount of radio-tracking for each owl were restricted by weather conditions and occasional equipment failures.

Small mammal snaptrapping was conducted on a biweekly basis by setting traps along transect routes in all habitats found on the study area during the radio-tracking period. An index to small mammal populations was based upon the number of small mammals caught per 100 trap-nights. All trapping results were pooled to provide an index to small mammal prey levels for each year of the study.

Relative abundance of grasshoppers for each year was based upon Canada Agriculture statistics (Dr. M. K. Mukerji, pers. comm.) from sample sites within eight kilometers of the study areas. All grasshopper numbers were pooled to provide an index to abundance for each year.

Regurgitated pellets found around nest burrows and perches were analysed (see Section 3.2 for details) to assess food habits in relation to movements and activity patterns.

Weather variables were recorded at the beginning and end of each observation period and when these variables changed. All inter-nest distances were measured by pacing and other distances were measured by car odometer from known map reference points.

4.2.4 Data analysis

For the purposes of this study, the home range of an adult male owl was defined as that area utilized for foraging, roosting, nesting and raising of young. The time period for these activities was from the first appearance of the owls on the study areas until they dispersed in August or September. This is similar to the Craigheads' (1956) definition of nesting range for migratory raptors. Areas of home ranges were determined by plotting all visual and radio-tracking locations for each owl on 1:20,000 scale photo maps. The smallest convex polygon which contained all the capture points (Southwood 1966, Jennrich and Turner 1969) was used to calculate home range size.

Activity patterns were evaluated using both visual observations and nocturnal radio-tracking data. All locations obtained from night-tracking, which were less than 50 m from the nest site, were considered to represent non-hunting activity. These were not included in analyses of foraging habitat utilization. Because all nest sites were less than 100 m from roads, where tracking stations were located, accurate determination of the owl's distance from its nest burrow was possible.

Habitat types of the study area were mapped based upon current and past agricultural activity, and vegetation composition (Appendix A). These types were plotted using photo maps and ground checks. The area of each habitat type within each owl's home range was calculated using a Graf/Pen Sonic Digitizer (Science Accessories Corp., Southport Conn.), and converted to percentages of the total home range. Habitat utilization for an individual owl was determined by counting the number of locations in each specific habitat type and comparing this observed number to the expected number had the owl used each habitat according to chance alone. This expected number of locations was calculated by multiplying the percentage of each habitat type in an individual's home range by the total number of locations. From these observed and expected values for each habitat type, a chi-square value was calculated to test the hypothesis that a foraging burrowing owl utilizes a given habitat type in proportion to its occurrence within that owl's home range. If the null hypothesis was rejected, individual confidence intervals were constructed for each habitat type using the Bonferroni normal statistic (Neu et al. 1974). This allowed determination of which habitat types were preferred or avoided during foraging. It was assumed that all owl locations were taken at random.

All statistical tests utilized the five percent level of significance.

4.3 Results

4.3.1 Histories of radio-marked owls

A knowledge of the breeding history of each radio-marked owl is necessary for the interpretation of the following descriptions of individual home range and movement.

Study area A

In 1982 a total of four pairs of burrowing owls attempted to nest at this site. During the second week of June, two pairs deserted due to avian predation of one nesting female and mammalian predation of eggs or young of the other pair. Both males of the two remaining pairs (owl 73 and 75) were radio-marked (Figure 4.1). The radio of owl 73 failed within 10 days after attachment and its home range was not calculated. Owl 75 raised three young to fledging. These two pairs of owls nested 170 m apart.

In 1983, three pairs of owls attempted to nest in this area. All three pairs deserted early in the breeding season due to predation and disturbance from a badger family. No radio-telemetry information was obtained from this study area in 1983.

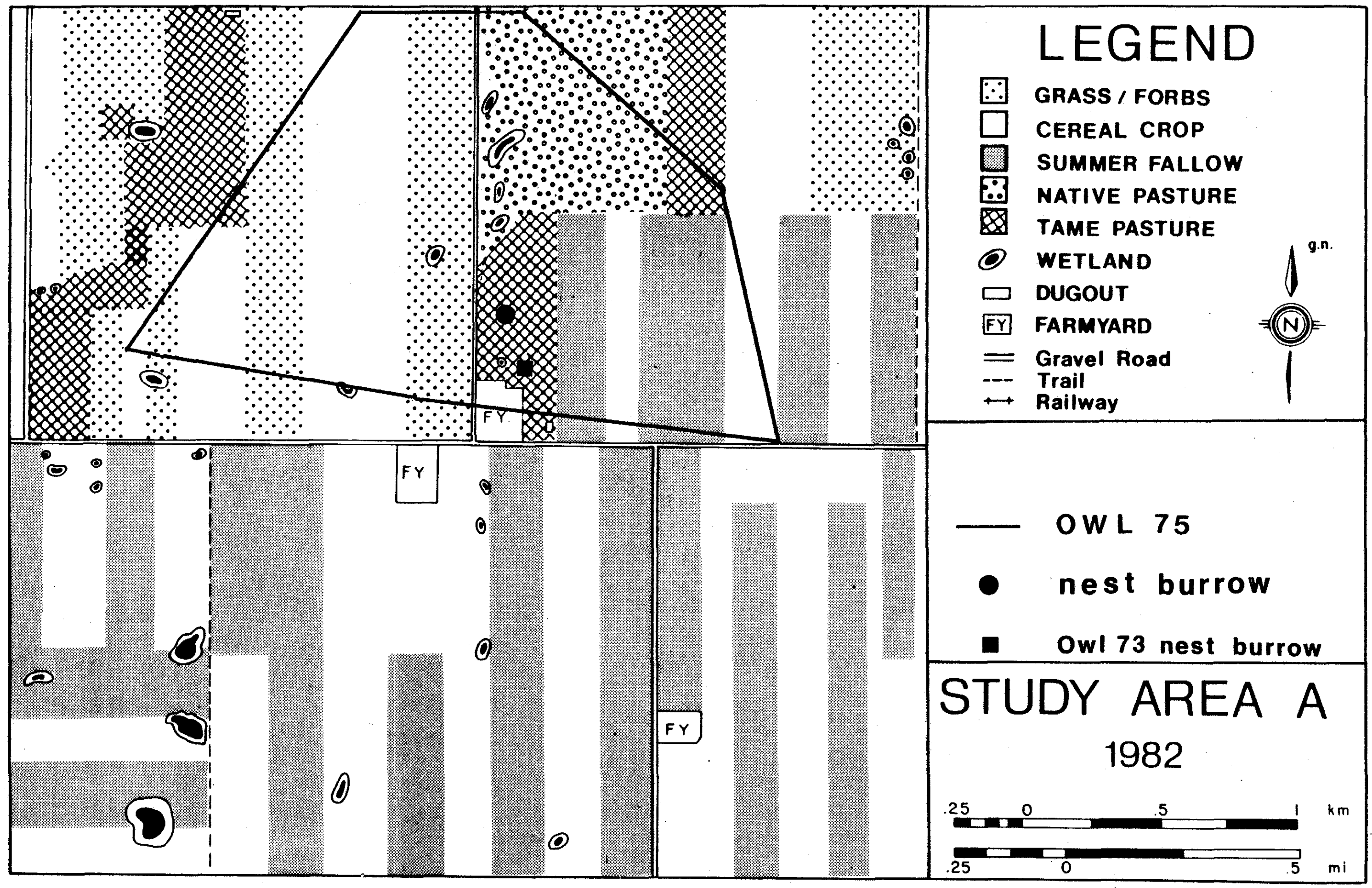


Figure 4.1. The home range of radio-marked owl 75, 1982. Width of roads includes rights-of-way.

Study area B

In 1982 a total of six breeding pairs of burrowing owls were present (Figure 4.2). An additional three pairs, assumed to have failed early in nesting, were intermittently observed during the summer. Four males of the six breeding pairs were radio-marked (owl numbers 76, 77, 78, 79). The two breeding males, not radio-marked, nested to the north of the radio-marked owls. The mean nearest-neighbour distance between nest burrows of all the breeding pairs was 214 m (range 165 to 351 m).

Owl 76 and its female raised four young to fledging. Owl 79 lost its female and all but one young on or near 10 July; it raised this young to fledging. Owl 77 lost its female and young to a mammalian predator approximately 9 July; it remained in the area of its nest burrow for the balance of the breeding season. The radio-transmitter of owl 78 failed within two weeks following attachment and the home range was not calculated. Owl 76 left the study area with its family on 17 August. The other three owls were last observed on 23 September when the study was terminated.

In 1983, breeding pair numbers decreased substantially throughout the entire study area. Only three pairs nested in Study Area B and no nonbreeders were observed during the summer (Figure 4.3). All three males were radio-marked and colour-marked (owls 78, 80, 82), however, the radio-transmitter of owl 80 failed 10 days after attachment and the home range was not calculated. Three days later this pair

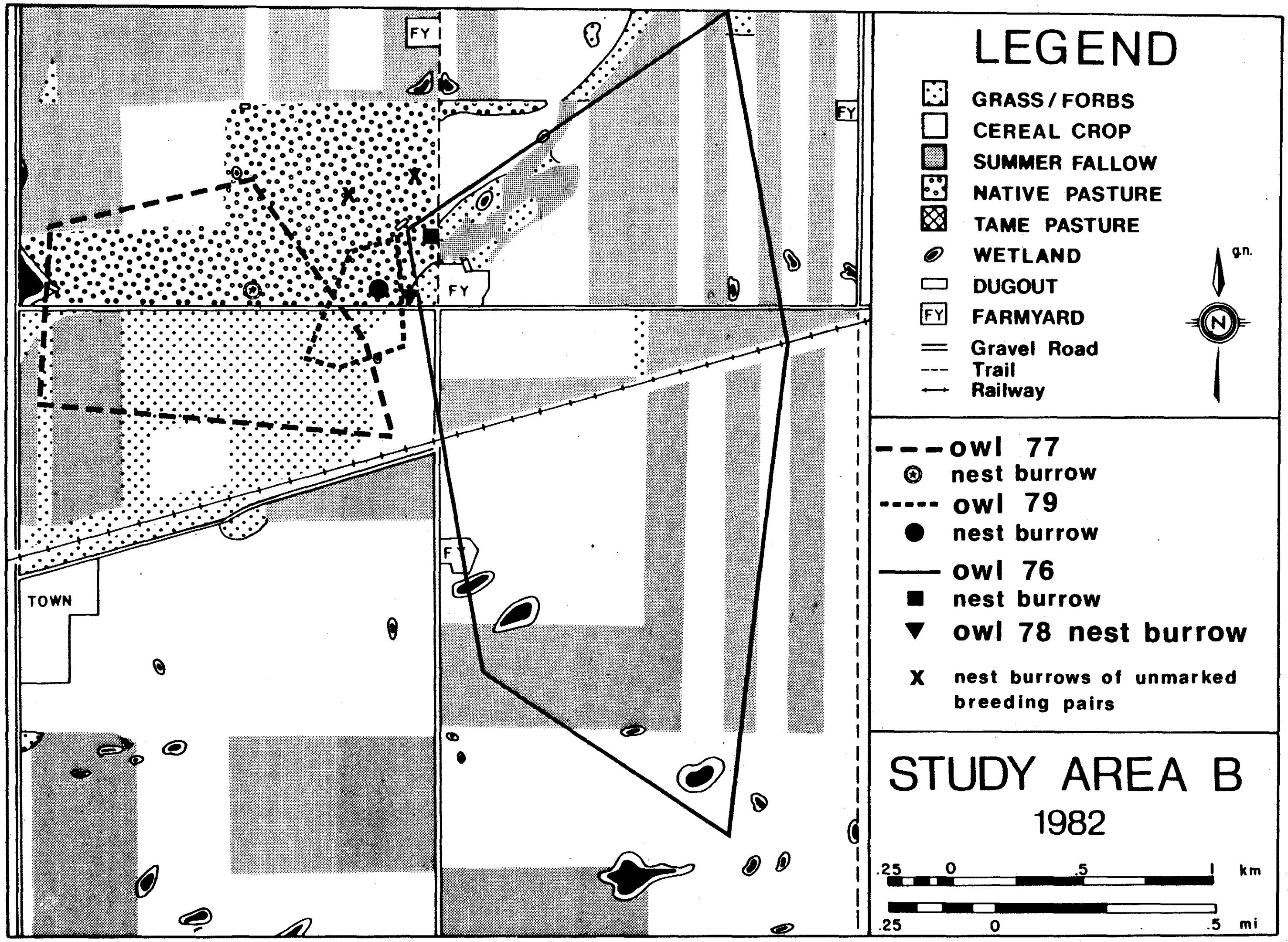


Figure 4.2. The home ranges of radio-marked owls 77, 79 and 76, 1982. Width of roads and railway includes rights-of-way.

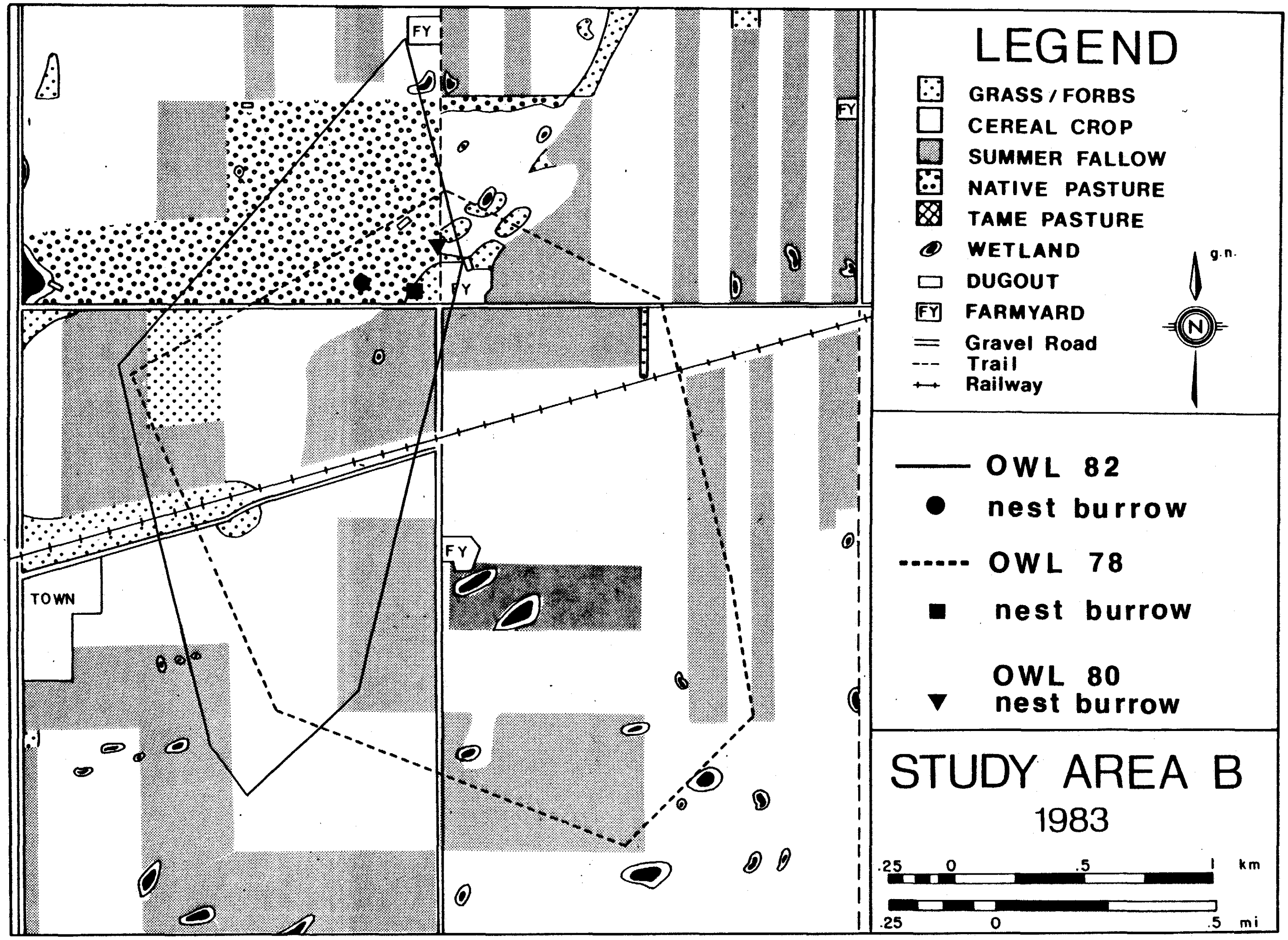


Figure 4.3. The home ranges of radio-marked owls 78 and 82, 1983. Width of roads and railway includes rights-of-way.

deserted after apparent destruction of the nest by a badger. The two remaining pairs nested 214 m apart. Owl 78 and its female raised six young to fledging, and it was tracked until 8 July when its radio failed; however, visual observations were obtained until 13 September. Owl 82 was radio-tracked until 25 June when it disappeared and was believed preyed upon.

Overall, a total of nine male owls in the two study areas were radio-marked; the radio-transmitters of three of these owls failed early in the breeding season. The number of telemetry locations for each of these three owls was insufficient (<25) to include in home range or foraging habitat utilization analysis. Telemetry and visual location information for the remaining six adult male owls consisted of 1005 locations for an average of 168 locations per owl (range 71-247).

This study focused upon breeding pairs nesting in association with one or more pairs within a 0.64 km^2 area. The information gained may not be applicable to lone breeding pairs or single owls.

4.3.2 Home range characteristics

Figures 4.1, 4.2 and 4.3 illustrate shapes and positions of home ranges of the six radio-marked owls for which sufficient data were collected. All home ranges were elongated polygons which radiated from the nest burrows away from their neighbours and into surrounding areas.

Table 4.1 summarizes the home range data for these six adult male owls. The overall mean home range size was 2.41 km^2 (range 0.14 to 4.81 km^2). The mean major axis length of home ranges was 2.43 km (range 0.67 to 3.41 km). The mean of the maximum recorded distance from the nest burrows was 1.74 km (range 0.47 to 2.75 km).

Biweekly home ranges were calclulated for four owls with adequate sample sizes (owls 75, 76, 77 and 78). In all cases the largest biweekly home ranges were evident during the last two weeks in June or the first two weeks in July. All subsequent biweekly home ranges decreased, while still centered around the nest burrows. The cumulative maximum home ranges were reached by July 31 for three of the four owls. In 1983 the fourth owl (78) removed its radio prior to July 15 while its home range was still increasing.

During any given biweekly period, the home ranges of adjacent radio-marked owls did not overlap suggesting some mechanism of spacing occurred during the breeding season. However, since not all adult males were radio-marked on the study area, it was impossible to determine whether territoriality occurred in the foraging areas. On a number of occasions during the high grasshopper year (1982), I observed from five to ten owls, both young and adults, hunting insects within a two hectare area of summerfallow. No obvious displays of aggression were observed. When entire home ranges were considered, overlap was apparent (Figures 4.2 and 4.3). Overlap was measured for neighbouring pairs of owls and ranged from 4.8 - 58.9 percent (mean 34.1 percent).

Table 4.1. Movement parameters of radio-marked owls, 1982 and 1983.

YEAR	DATES MONITORED	OWL	NUMBER OF YOUNG FLEDGED	TOTAL NUMBER OF RADIO FIXES	HOMERANGE SIZE (Km^2)	MAJOR AXIS (Km)	MAX DISTANCE FROM NEST BURROW (Km)
1982	13 June - 15 Aug.	76	4	211	3.43	3.41	2.75
	13 June - 15 Aug.	77	0	175	1.04	1.70	1.02
	18 June - 14 Aug.	79	1	111	0.14	0.67	0.47
	15 June - 26 Aug.	75	3	247	2.04	2.60	1.46
	Mean			186	1.66	2.10	1.43
	SE			29	0.71	0.59	0.49
1983	6 June - 8 July	78	6	190	4.81	2.81	2.43
	9 June - 23 June	82	0	71	3.02	3.37	2.32
	Mean			130.5	3.92	3.09	2.38
	SE			59.6	0.90	0.28	0.06
	Overall Mean			167.5	2.41	2.43	1.74
	SE			26.6	0.69	0.43	0.36

In 1982, average observed home range size was smaller than that observed in 1983 although the 1982 radio-marked owls were tracked four to five weeks longer. Even greater differences in home range sizes may have been evident if owls had been tracked for equal periods of time.

4.3.3 Activity patterns

During the beginning of the 1982 radio-tracking study, the observation periods were spread evenly over a 24-hour period. Within three weeks it became obvious the male owls remained near their nest sites during daylight hours (Figure 4.4). Owls could be observed foraging at all hours of the day and night, but spent most of the daylight hours roosting or loafing within 50 m of the nest burrow and/or surrounding burrow(s). The adult owls were occasionally seen foraging for insects farther than this approximate 50 m limit during the day, but they were never seen to travel farther than 250 m from the nest burrow. Adult owls were never observed foraging for, or carrying small mammals during the day.

Peak foraging hours (as determined by flights greater than 50 m from the nest burrow) occurred between 2000 and 0630 hours (Figure 4.4). During this period adult male owls were much more active and engaged in long-distance flights and hovering suggestive of foraging for small mammals. Most of this foraging activity began within one hour of sunset and adult owls could usually be seen back in the vicinity of the nest burrow at sunrise.

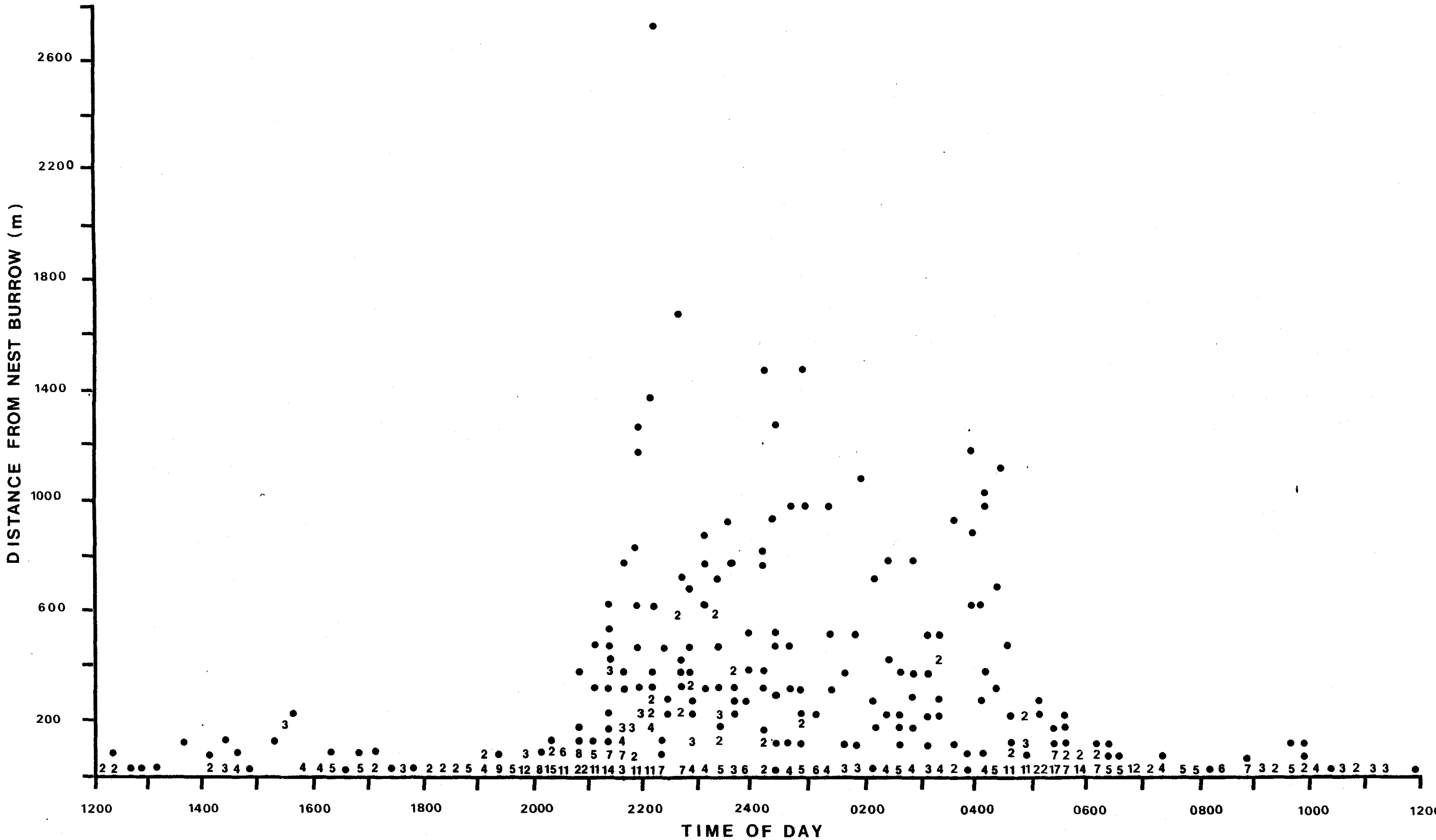


Figure 4.4. Distance traveled by burrowing owls from nest burrows in relation to time of day, as determined by visual and telemetry observations, June to August, 1982.

4.3.4 Foraging habitat utilization

Five of the six radio-marked owls exhibited significant ($p < .01$) preference or avoidance of particular habitat types during foraging. The accumulated chi-square values for each owl are summarized in Table 4.2. Table 4.3 presents the owls' preference, avoidance or neither for the habitat types found within their respective home ranges as determined by the Bonferroni normal statistic (Neu et al. 1974). The burrowing owls, with one exception, consistently selected grass/forb areas more often than all others for foraging. When this category was divided into its components (Appendix A), rights-of-way and uncultivated areas represented the habitat types which were utilized to a greater degree than by chance alone. Crop and native pasture were generally avoided in comparison to their occurrence within the home ranges.

Owl 82 appeared to avoid summerfallow and crop areas, similar to the other owls. However, the apparent avoidance not was significant, and it is believed that the small sample size of telemetry locations ($n = 38$) may not have allowed detection of a small, but real, difference in habitat use.

Pooling of individual owl's habitat utilization results was avoided because: 1) time intervals of radio-tracking differed due to trapping successes and random equipment failures; and 2) home ranges overlapped and avoidance or territoriality on the foraging grounds may have

Table 4.2. Accumulated chi-square values, degrees of freedom and probability values for habitat utilization analysis of radio-marked owls.

YEAR	OWL	NUMBER RADIO FIXES GREATER THAN 50 M	X^2 VALUE	DEGREES OF FREEDOM	PROBABILITY
1982	75	98	55.2	5	$p < .01$
	76	62	269.2	4	$p < .01$
	77	87	20.3	4	$p < .01$
	79	54	11.7	3	$p < .01$
1983	78	134	376.7	4	$p < .01$
	82	38	8.1	4	Not significant

Table 4.3. Foraging habitat utilization of radio-marked owls in Study Areas A and B, 1982-83. Observed/expected number of locations for each habitat type.

Cover type	Radio-marked owls 75	76	77	79	78	82
Crop	13/31.9***	8/31***	1/3.8*	8/8.3	27/65.5***	8/14.4
Summer Fallow	18/15.8	28/28.1	6/9.7	NA	41/52.5	16/9.6
Native Pasture	3/17.3***	3/0.4	19/32.5	8/18.8***	2/5.6	9/10.4
Tame Pasture	18/9.1	NA	NA	NA	NA	NA
Wetland	1/1.2	0/0.9	0/0.6	0/0.4	5/0.9	0/0.4
Grass/Forbs	45/22.3***	23/1.9***	61/40.3***	38/26.4**	59/7.9***	5/3.4

NA Habitat not available in owl's home range.

* $p < .05$
** $p < .01$
*** $p < .001$

biased results. Although these results were not pooled, overall numbers of locations show a preference for grass/forb areas. Out of a total of 473 locations greater than 50 m from the nest burrow, an average of 49 percent were determined to be in 23 percent of the total habitat available in the owls' home ranges.

4.4 Discussion

4.4.1 Evaluation of transmitter design

There are many published examples of the various effects of radio-transmitter attachment to wild birds. The back-pack or harness method appears to be the most commonly used, but has various effects on the behavior of marked birds. For example, Brander (1968), Nicholls & Warner (1968) and Herzog (1979) found no evidence of aberrant behavior caused by the attachment of the radio transmitter harness to either ruffed grouse (Bonassa umbellus), large owls (Strigidae), or spruce grouse (Canachites canadensis), respectively. However, Ramakka (1972), Boag (1972) and Greenwood and Sargeant (1973) demonstrated decreased levels of activity and food comsumption, atypical courtship activities, increased weight loss and skin irritation around the transmitter in woodcock (Philohela minor), red grouse (Lagopus lagopus scoticus) and waterfowl, respectively.

Amstrup's (1980) radio collar design had been tested only on sharp-tailed grouse although Butts (1973) attached plastic poncho markers to two burrowing owls without success. This method was chosen for use on burrowing owls in this study because: 1) it was felt the harness design was too restrictive and heavy for use on a small raptor, and 2) the antenna on a tail-mounted design (Kenward 1978) would contact the ground restricting the radio transmitter's range. It was also believed that the tail-mount package was too large for the owls' short tails.

Attachment of the prefabricated collar required two people, one to restrain the owl and the second to fit the package. This procedure could be completed in less than 10 minutes. All radio-marked birds were released directly into their nest burrows and reappeared again within two hours. All nine radio-marked birds displayed initial annoyance (less than one day) at the collar and were seen tugging at it with their beaks.

In 1982, owl 78 was recaptured twice and the radio collar checked. There was no evidence of skin irritation, but a small amount of feather wear was evident under the chin where the collar expanded to hold the transmitter. Two adult owls which were held in May 1982 to test the collar design displayed no obvious skin irritation or feather wear after four weeks. In 1983, two of the owls were able to tear through the single layer of material and remove the collar. If the 1983 design is used, it is advised that a strip of soft leather be overlapped and sewn around the entire neck hole to increase the poncho strength.

All radio-marked birds were monitored visually and, except for an occasional tug at the collar, their behaviour appeared normal. The collar appeared to have no affect upon the survival of the owls. One out of nine radio-marked birds disappeared during the two year study.

4.4.2 Home range characteristics

There is little comparative information available on home range size and characteristics for the burrowing owl. Previous authors have been restricted to diurnal observations only. Butts (1973) reported the radii of home ranges of burrowing owls in Oklahoma to be less than 1.5 mi (2.4 km). Grant (1965) states that two pairs of burrowing owls in Minnesota confined their activities, including hunting, to areas of 16 and 12 acres (0.065 and 0.049 km^2) respectively.

In other studies, adults and young have been observed during nocturnal hunts varying distances from the nesting areas. Hennings (1970) reported that owls apparently ranged at least 0.6 mi (1 km) from their burrows in California. Butts (1971) observed young owls 1.0 to 1.5 mi (1.6 to 2.4 km) from their nests at least six times during July in Oklahoma. An adult bird was seen 0.7 mi (1.1 km) from its nest on a moonless night. He found trips of more than 0.7 mi (1.1 km) to be uncommon and males generally hunted within 0.25 mi (0.4 km) of the nest burrow. Hamilton (1941) found owls flew at least 1.0 mi (1.6 km) to obtain crayfish in Colorado.

In 1982, there were varying nesting outcomes which were believed to be associated with the large variation in home range size. For example, the two owls (75 and 76) that had the largest home range sizes (2.04 and 3.43 km^2, respectively), fledged the greatest number of young. Owls 77 and 79 which lost all or most of their families, had smaller home ranges (1.04 and 0.14 km^2, respectively).

There was some evidence, although not statistically significant, to suggest the variation in home range size between 1982 and 1983 was, in part, due to differences in food availability. Table 4.4 presents overall food availability indices determined from small mammal trapping and grasshopper surveys. Although there is no significant difference in mean home range size or mouse populations between 1982 and 1983, the grasshopper index does show a significant difference ($p < .001$, $t = 3.57$, $df = 86$) between years. Mean home range size appeared inversely proportional to grasshopper availability. Schoener (1968) found home ranges of raptors to be significantly correlated with an index of the numerical density of their prey and Rusch et al. (1972) found greater nesting densities of great horned owls (*Bubo virginianus*) when prey were abundant.

Analysis of regurgitated pellets showed a rapid increase in consumption of arthropods, predominantly grasshoppers, near the end of June and early July. At this time, grasshoppers had reached maturity and were quite conspicuous and available. This corresponds to the reduction in sizes of the biweekly home ranges. The adult owls were able to obtain adequate food for themselves and their young in a smaller area utilizing the abundant grasshoppers.

The cumulative maximum home ranges were reached by 31 July in all cases. Any young produced by the radio-marked adults were five to six weeks old and taking a greater proportion of their own food at this time.

Table 4.4. Food availability indices for 1982 and 1983.

YEAR	MEAN HOME RANGE SIZE (KM^2)	MOUSE POPULATION INDEX # MICE/100 TRAP NIGHTS	GRASSHOPPER POPULATION INDEX MEAN NO./SQ. M.
1982[1]	1.66	3.1	5.28
1983[2]	3.92	3.6	3.06

1. Study area A and B combined.

2. Study area B only.

4.4.3 Activity patterns

Because of its high visibility and diurnal activity during the nestling period, many researchers have reported this species to be strictly diurnal. Marti (1969) stated they were apparently poorly adapted for nocturnal foraging as Dice (1945) found they could not locate dead mice in light intensity of 26 (10^{-5}) foot candles. Best (1969) states that burrowing owls are primarily nocturnal during winter and primarily diurnal in summer.

Nocturnal activity was found to occur in a number of studies in the western United States. Columbe (1971), Ross (1974) and Thomsen (1971) reported owls were primarily nocturnal and crepuscular. Thomsen goes on to write "birds caught before sunrise always had distended stomachs, whereas those caught in the early evening did not, indicating that they foraged at night". Gleason (1978) found burrowing owls in Idaho to restrict most daytime foraging to within 100 m of the nest burrow, and to leave the nest area between 2200 and 2300 h for long-distance foraging.

The results of this study confirm those studies which suggest that the majority of foraging occurs at night. The male owls in this study were predominantly nocturnal; they flew long distances to find food during darkness. However, from the time the young hatched until their independence, the adults could also be observed actively foraging close to the nest burrow during daylight hours. The activity patterns of the burrowing owls also reflected the activity patterns of their prey. Small mammals, especially *Microtus* spp. and *Peromyscus* spp., were the major prey species taken during May and June as determined by pellet analysis (Section 3.3). During this time, the male owls were predominantly nocturnal. As the percentage of grasshoppers in the diet increased during July and August, diurnal foraging was frequently observed near the nest burrows. However, the owls continued nocturnal foraging throughout the breeding season as evidenced by the continued occurrence of small mammals in the diet.

As the young developed hunting skills, the diurnal activity of the adults slowed; they were observed roosting and loafing near the nest burrows during daylight as the season progressed. The adults' nocturnal activity also decreased as the young developed, but they exhibited no behaviour to support the theory that they were crepuscular.

4.4.4 Foraging habitat utilization

Very limited information exists regarding habitat selected for foraging by burrowing owls. Scott (1940) estimated land use within a 0.25 mi radius of three nest burrows in Iowa, but did not specify how he arrived at these estimates. A few authors have reported agricultural areas to be selected for during foraging. Butts (1973) found owls in Oklahoma foraged extensively in wheat fields in the spring. Wheat fields supported substantial rodent populations, and he believed these were utilized during early spring before insects became numerous. Gleason (1978) also found nesting burrowing owls used montane voles (*Microtus montanus*) found in agricultural areas significantly more than pairs that nested away from agricultural areas in Idaho.

The results of this study suggest that crop areas were avoided by the radio-marked owls. Not enough information was collected regarding small mammal numbers for individual habitat types to make any statistical tests meaningful, however, partial results indicated crop areas did have the greatest densities of small mammals. The avoidance of crop areas by adult owls may reflect prey availability rather than absolute density. Bechard (1982) found the vegetative concealment of the prey more important than prey biomass in the selection of foraging sites by Swainson's hawks. It may also reflect the owls' tendency to prey heavily upon grasshoppers at this time of year; because of heavy pesticide spraying in cropland, the greatest numbers of grasshoppers were found in rights-of-way and uncultivated areas, which were the areas most extensively used by radio-marked owls.

Utilization of crop areas may have occurred early in the breeding season as determined by Butts (1973) in Oklahoma. The timing of this telemetry study could have underestimated the importance of foraging for small mammals in agricultural areas during May and early June before insects became available.

4.5 Summary

The following aspects are apparent from this study:

1) Overall home ranges of radio-marked adult male burrowing owls averaged 2.41 km^2 (range 0.14 to 4.81 km^2). Home range sizes appeared to be inversely correlated with an index of the numerical densities of their prey, particularly grasshoppers (Acrididae), and positively correlated with the number of young fledged. The size of the home ranges reported here are larger than those previously reported in the literature.

2) Biweekly home range sizes peaked by mid July and decreased thereafter. This coincided with an increase in grasshopper numbers and availability. Owls required less foraging area to feed themselves and/or families.

3) During any given biweekly period home ranges of adjacent owls did not overlap indicating some mechanism of spacing may have occurred on the foraging areas. Total home ranges did show areas of overlap (range 4.8 - 58.9 percent).

4) In contrast to previous studies, burrowing owls were predominantly nocturnal. Peak foraging hours, characterized by long distance flights occurred between 2000 and 0630 hours. During daylight hours, owls were predominantly observed loafing or roosting within 50 m of their nest burrows. Some foraging for insects did occur when the young were still dependent. As the young developed, adult owls became strictly nocturnal.

5) Grass/forb habitat types, which included road rights-of-way, hayland, ungrazed pasture and uncultivated areas, were preferred for

foraging by adult male burrowing owls. Crop and grazed pasture were generally avoided in relation to their occurrence within the home ranges. Because of the heavy pesticide spraying in the crop areas and the sparse vegetation in the pastures where the nest burrows were located, the greatest densities of grasshoppers, a major prey item, were located in the grass/forb areas.

5.0 MANAGEMENT RECOMMENDATIONS

1) Through the use of radio-telemetry, it has been concluded that owls require only small parcels of closely-cropped pasture with an adequate supply of nest burrows to breed, and prefer to forage in areas of denser vegetation which support greater densities of small mammals and insects. The preferred nesting habitat requirements of short grass, openness of site and burrow availability (Wedgwood 1978) can be met by managing the existing historic nest sites and maintaining or increasing their numbers. The need to set aside large expanses of prairie for the preservation of the species appears unnecessary. Possible means of preservation include: a) a program to subsidize the landowner or an outright purchase to maintain these small (< 0.64 km^2) farmyard pastures in their present condition;
b) maintain the ground squirrel populations on these areas at a level which will supply adequate numbers of burrows. If availability of burrows appears to be a limiting factor, the installation of artificial burrows (Collins and Landry 1977) may be required.

2) Previous studies have found higher densities of small mammals in cereal crops (Butts 1973, Gleason 1978) and a corresponding increase in the numbers of young burrowing owls fledged. Areas of cereal crops, intermixed with hayland and uncultivated areas of dense vegetation, should supply adequate habitat types for

prey species utilized by burrowing owls to maintain adequate prey densities within one kilometer of nest sites.

3) Reduction or elimination of the limiting factors to population recruitment is needed: a) nest failures and nestling mortality caused by mammalian predation are an important concern. Both nest success and numbers of young fledged per successful nest could be increased through predator control in and around areas of known nest sites; b) the loss of burrowing owls to vehicle collisions was an important mortality factor predominantly affecting fledgling owls . Therefore any acquisition or preservation of land for nest sites or restocking programs should involve areas located at least 3 km from secondary roads; c) reduce or eliminate pesticide spraying and use of rodenticides within a 3 km radius of nest sites. Reduction of the ground squirrel population may have an adverse effect upon burrow availability and pesticide spraying reduces the densities of insect prey. Secondary poisoning of burrowing owls from contaminated prey species may also cause mortality. Compensation to farmers for damages caused by these measures may be necessary.

These management recommendations apply to burrowing owls during the breeding season. Unfortunately six months of the year the owls are on migration routes and wintering areas, both of which are unknown at present. Assessment and mitigation of limiting factors during this time period is currently not possible.

The relatively low production and high mortality on the breeding grounds, both due to natural and man-induced causes, and a progressive loss of habitat suggest the breeding owl numbers in Saskatchewan can be expected to continue to decline.

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APPENDIX A. Habitat types and vegetation found on Study Areas A and B.

HABITAT	STUDY AREA	DESCRIPTION
Crop	A, B	Areas of cultivated cereal crops which were plowed, planted, sprayed with pesticides and herbicides, and harvested during the breeding season.
Summerfallow	A, B	Areas of land which were plowed but not seeded to destroy weeds and conserve soil moisture.
Native pasture	A, B	Grazed pasture dominated by the Mixed Grass Prairie (Coupland and Rowe 1969) of which the major grass species were spear grasses (*Stipa* spp.), June grass (*Koelaria cristata*), wheat grasses (*Agropyron* spp.) and blue gramma grass (*Bouteloua gracilis*). Subdominant species associated with overgrazing and alkali conditions included: pasture sage (*Artemisia frigida*). wild barley (*Hordeum jubatum*),

		alkali grass (*Distichlis stricta*), Russian thistle (*Salsola Kali*), and seablite (*Suada depressa*). Clumps of snowberry (*Symphoricarpos occidentalis*), silverberry (*Eleagnus commutata*) and wild rose (*Rosa* spp.) were found on the moisture areas.
Tame pasture	B	Grazed pasture which was tilled and planted to crested wheat grass (*A. cristatum*), brome grass (*Bromus* spp.), alfalfa (*Medicago sativa*) or Russian wild rye (*Elymus junceus*). Due to overgrazing and alkali soils, wild barley and pasture sage were common.
Wetland	A, B	A general category which included all classes of wetlands on the study areas as defined by Millar (1976): wet meadow, shallow marsh, emergent deep marsh and shallow open water.
Farmyard	A, B	Included houses plus associated outbuildings, barns, equipment,

		feedlots and hedgerows.
Grass/forb	A, B	This category included four subcategories which were lumped together because of similar vegetation height (plants greater than 30 cm) and density.
	A, B	Rights-of-way: areas bordering roads and railway lines planted to brome grass, wheat grasses and sweet clover (<u>Melilotus</u> spp.).
	A, B	Hayland: areas planted to tame grasses (see tame pasture plants) which were cut and baled for livestock feed. During the course of the radio telemetry study, none of these areas were cut.
	B	Ungrazed native pasture: small areas which were never incorporated into cropland or pastureland. The vegetation was similar to grazed native pasture, but at least 30 cm tall.

A, B — Uncultivated areas: areas disturbed by man in the course of roadbuilding, clearing for cultivation, rock piles. The largest areas in this category included cultivated fields left as summer-fallow, but not plowed to reduce vegetation during the season. These areas had grown thickly with a variety of grasses and forbs including wild barley, brome grass, sweet clover, wheat grasses, thistles (*Cirsium* spp., *Sonchus* spp.), Russian thistle, wild oats (*Avena fatua*), foxtail (*Setaria* spp.), *Rumex* spp., *Kochia* spp., goldenrod (*Solidago* spp.) and a variety of species from the mustard (Cruciferae) family.