CENSUS METHODOLOGY AND HABITAT USE OF LONG-BILLED CURLEWS (*Numenius americanus*) IN SASKATCHEWAN

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ABSTRACT

The Long-billed Curlew (*Numenius americanus*) is currently listed as a species of 'Special Concern' by the Committee on the Status of Endangered Wildlife in Canada mainly due to historic declines as a result of over-hunting and habitat loss. Despite its listing, the curlew has received little scientific attention in Canada.

My main objectives were to evaluate census methods and determine seasonal habitat use by curlews in southwestern Saskatchewan. In 1999 and 2000, point counts were made every 1600 m at 200 sampling points along various road networks. I compared the effectiveness of a traditional listening census technique with call response surveys for detecting curlews. I found that call response surveys are relatively ineffective at detecting birds in the field. During the surveys, all curlews observed were recorded and the habitat within the sampling points was classified as native prairie, tame pasture, stubble, fallow, tame hay, fall/winter crop or spring/summer crop. The census occurred during the pre-lay, incubation, and post-hatch periods, which enabled me to assess whether there was a shift in habitat use over the summer. My results indicate that curlews generally prefer native prairie grassland and avoid areas of stubble, fallow and tame hay. Significantly more curlews than expected were observed in spring/summer cropland during the post-hatch periods. Tame grasslands were typically used in relation to their relative abundance.

In 2000, habitat measurements were taken and wetland data were collected. Curlew occurrence was best predicted by shorter vegetation, higher proportions of grass and bare ground, and less coverage of *Selaginella*. Curlew abundance increased with the presence of ephemeral and alkali wetlands, as well as the total number of wetlands during the pre-lay period in 1999.

Radio telemetry data indicate that chicks in areas with fragmented habitats tended to move longer distances and cover greater areas than those in large areas of grassland.

Geographical Information System technology and logistic regression analyses revealed Landsat 7 bandwidths 7, 3, and 2 to be effective predictors of curlew occurrence in sampling points. The logistic regression model containing these variables was used in the attempt to generate a probability surface indicating areas of probable curlew occurrence in southern Saskatchewan.

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1. INTRODUCTION

The Long-billed Curlew (*Numenius americanus*; Order Charadriiformes; Family Scolopacidae) is the largest shorebird in North America. Curlews occupying the northern part of the species' range are recognized as a distinct subspecies, *Numenius americanus parvus* (Allen 1980, Cannings 1999). Despite its size and conspicuous nature, the Long-billed Curlew has historically received little scientific attention. This is at least partially a result of the ecological niche occupied by upland shorebirds. Shorebird studies have mainly focused on species inhabiting wetlands, while upland studies tend to favour passerines, raptors, or game birds (Morrison et al. 1994). Rigorous studies and monitoring efforts of curlews are becoming more numerous as conservation concerns gain more prominence (Cannings 1999; Saunders, in review).

Curlews were formerly numerous across the North American prairies. However, over-hunting and the loss of grassland habitat resulting from agriculture caused significant declines in curlew numbers. These birds are now extirpated from several areas of their historic range. The lack of scientific information regarding curlew population sizes, distributions and trends makes it difficult to assess the current status of the population. Nonetheless, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recently listed the Long-billed Curlew as a species of 'Special Concern' (formerly 'Vulnerable') indicating that characteristics of the bird make it particularly sensitive to human activities or natural events (Saunders, in review).

Knowledge about population size, distributions and trends is of critical importance to undertaking the effective conservation of a species (Grant et al. 2000). My study was designed to determine an effective, repeatable large-scale census technique for detecting curlews that could then be implemented in future monitoring programs. The data collected in this study could form a strong basis for such efforts and provide insight into curlew population trends in southwestern Saskatchewan.

The breeding biology and relative importance of various habitats to Long-billed Curlews in Saskatchewan has yet to be identified. This study was designed to determine the relative importance of different habitat types, namely native prairie, tame grassland, tame hayland, cropland, and wetland ecosystems, to this species in southwestern Saskatchewan and provide a basis for management decisions.

The ability to identify areas of high abundance for a species is essential as it allows designations for conservation efforts to be aimed at the most appropriate sites (Grant et al. 2000). I set out to create a probability surface indicating areas of probable curlew occurrence across the species' range in Saskatchewan.

1.1 Physical description

The Long-billed Curlew, one of the largest shorebirds in the world, can attain a body length of up to 65 cm at maturity, and a mass of about 1 kg. Its characteristic down-curved bill can reach a length of 20 cm. Adults are sexually dimorphic with females having longer bills and slightly larger bodies than males (Redmond and Jenni 1986).

Adult plumage is mottled, sandy brown on the back, with brown streaking on the neck and a lighter belly. In flight, cinnamon coloured underwings are evident. The curlew's wingspan can be as much as 1 m (Allen 1980). Juvenile curlews have much shorter bills and less streaking on the breast and throat.

The Long-billed Curlew has long, gray legs, which coupled with its long bill are morphological adaptations for life as a shorebird. Although curlews are taxonomically part of the Order Charadriiformes (or shorebirds), in the breeding season they are primarily ground-dwelling, upland birds. The curlew gets its name from its loud, unique call, "curleeeeeeuuu". It has been said that the curlew embodies the spirit of the open prairie more than any other bird (Taverner 1926; Bent 1929).

1.2 Breeding biology and behaviour

Long-billed Curlews are a late-maturing, long-lived species with a relatively low annual reproductive output. Average longevity is believed to be ten years and age at first breeding is estimated to be two to three years for females and three to four years for males (Redmond and Jenni 1986; Allen 1980).

Long-billed Curlews are migratory, usually returning to their breeding grounds in Saskatchewan between 8 and 20 April (Renaud 1980). Actual migration routes have yet to be identified. Typically, only a few birds are reported initially on the breeding grounds, but within one week substantial numbers return.

Occasionally, small flocks are observed, but these disperse before nesting commences (Redmond and Jenni 1986; Allen 1980).

Curlews exhibit site-fidelity and appear to nest in social clusters (Allen 1980). Males are significantly more philopatric to natal areas than females (Redmond and Jenni 1982). However, females appear to be equally loyal to previous nesting territories and more likely to disperse as a result of disturbance (Redmond and Jenni 1982). The same territories appear to be used in subsequent years (Allen 1980; Pampush and Anthony 1993). Curlews have been observed using the same areas in southwestern Saskatchewan year after year (A.R. Smith, pers. comm.). However, it is not known for certain whether sites are re-used by the same individuals.

Long-billed Curlews are territorial and some individuals arrive on territories already paired (Allen 1980). As for many other bird species, a variety of courtship and territorial behaviours are displayed with vocalizations playing a prominent role. After arrival from migration, males are extremely vocal and spend most of their time performing undulating flight displays above their territories. Once a female chooses a mate, pair formation rituals such as a "scrape ceremony" are performed. The female will eventually accept a sequence of pre-copulatory behaviours before copulation occurs (Allen 1980). Curlews have a socially monogamous mating system, and the level of displays appears to be reduced between previously bonded pairs (Allen 1980; Redmond and Jenni 1982).

A nesting site is originally formed as a scrape by the male, and is subsequently selected by the female. The nest bowl is made deeper by continued scraping. Nest material, typically consisting of nearby vegetation such as grass or straw, is added to the nest bowl (Allen 1980). In Washington State, the average diameter of the nest bowl was 201.2 mm (Allen 1980; n= 59). Small rocks are occasionally observed among the eggs. Nests are often located in close proximity to conspicuous objects, such as rocks, dung, dirt mounds and exposed roots (Allen 1980; Redmond and Jenni 1986; Cochran and Anderson 1987).

Long-billed Curlews have evolved several adaptations for ground nesting, including elaborate, anti-predator behaviours. Curlews, particularly males, aggressively "dive-bomb" perceived predators. This involves cooperating extensively with neighbours to mob potential threats. Nesting in social clusters presumably facilitates such social and aggressive behaviour. Nests were 250 m to 500 m apart in preferred habitat in Washington (Allen 1980). The colouration of adult plumage is another of the curlews' adaptations to ground nesting. Adults sit tight on the nest and are extremely well camouflaged, making nests difficult to find (Allen 1980; pers. obs.). As previously mentioned, nests are often found in close proximity to conspicuous objects, which typically increases crypsis (Allen 1980; Cochran and Anderson 1987).

In Saskatchewan, egg-laying usually occurs at the beginning of May, but with substantial variation between pairs (Renaud 1980). As with most shorebirds, the standard clutch size is four eggs (Maclean 1972). Egg-laying occurs over a period of four to seven days, and incubation begins after the final egg is laid (Redmond and Jenni 1986; Allen 1980). Eggs are buffy-olive with dark brown blotches or speckles, a pattern that enhances crypsis (Hill 1998). Curlews lay only one clutch per season and re-nesting has not been documented (Redmond and Jenni 1986; Sadler and Maher 1976).

Incubation is shared between the sexes and ranges from 27 to 30 days. Generally females incubate during the day and males at night. Nest relief occurs at approximately the same time each day. Both males and females are involved in nest defense and will chase and "dive-bomb" predators as necessary (Redmond and Jenni 1986).

Eggs hatch synchronously within nests. Often all chicks hatch within five hours (Allen 1980; pers. obs.). Curlews have precocial young. They hatch with their eyes open, covered with down, and are able to walk shortly after hatching. Chicks usually leave the nest within hours of hatching. Although they are precocial and not fed by adults, chicks still rely on parents for brooding at night, shading during the day, and to provide warning about potential predators (Redmond and Jenni 1986; Allen 1980).

Young chicks have cryptic coloration (a creamy colour with dark brown splotches on their backs). This coupled with crouching and remaining motionless in the vegetation in response to warning calls makes them particularly difficult to locate (Redmond and Jenni 1986; pers. obs.). A series of specific calls indicate the presence of predators and others cause the chicks to hide (Allen 1980). As chicks grow older, they tend to run using their long legs to escape from intruders and then freeze their position usually in tufts of tall vegetation (pers. obs.). As in many birds, adult curlews will often feign injury or perform an enticement-run to lead predators away from young (Allen 1980).

Adults appear to lead broods in general directional movements, while allowing chicks to wander independently under their watch (Allen 1980). In Idaho, Redmond and Jenni (1986) found that broods were likely to remain within 100-300 m of the nest for one to five days after hatching. Long distances were traveled thereafter, with broods covering large areas (average seasonal coverage= 500 ha). Sadler and Maher (1976) found that a banded chick in Saskatchewan moved 6.5 km within six days of hatching.

Males and females initially share parental responsibility. However, most females abandon the brood when the chicks are two to three weeks old. Males continue to exhibit parental behaviour and tend to remain with the brood until fledging occurs, approximately six weeks after hatching (Allen 1980; pers. obs.).

According to Allen (1980), young fledge when they reach 41 to 45 days of age. In Saskatchewan, fledged young have been observed as early as June 28 (1999, near Big Stick Lake; W. Harris pers. comm.). In southwestern Saskatchewan, most juveniles are first capable of flight during mid-July (A.R. Smith, pers. comm.). Annual productivity is low, estimated at only 0.50 young fledged per pair in Idaho (Redmond and Jenni 1986).

In late July and early August, adults and juveniles form small family groups prior to staging. These smaller groups join together to form a large flock at staging sites, where they spend time loafing, resting and feeding prior to migration (Allen 1980). Observations suggest that curlews gradually depart for migration in smaller flocks (Allen 1980; Renaud 1980). Typical fall migration dates for Saskatchewan are between 8 -16 August (Renaud 1980).

1.3 Feeding

Long-billed Curlews are opportunistic feeders on their breeding grounds, capable of exploiting a wide variety of prey types according to availability and vulnerability. In Idaho, curlews were reported to consume large earthworms and other invertebrates early in the season. With increasing temperatures curlews seemed to focus on carabid beetles, until the emergence of grasshopper species later in the season (Redmond et al. 1982). Carabid beetles were also a major prey source in Washington (Allen 1980). It is assumed that curlews also consume subterranean prey as they are frequently seen probing in loose soils (Allen 1980; pers. obs.). There are reports of Long-billed Curlews depredating the altricial nestlings of Horned Larks (*Eremophila alpestris*; Sadler and Maher 1976) and Lark Buntings (*Calamospiza melancorys;* Timken 1969; Goater and Bush 1986). On occasion, curlews have been observed feeding on amphibians (Timken 1969).

On their wintering grounds, curlews forage in both intertidal habitats and coastal pastures. In intertidal zones, they primarily eat shrimp, crabs, worms (Nereidae), and small fish (Colwell and Mathis 2001; Stenzel et al. 1976), while earthworms appear to be the major prey item taken in coastal pastures (Colwell and Mathis 2001).

The curlew bill is well adapted to feeding on both the breeding and wintering grounds. In pastures, the length and curvature of the bill allows the birds to see just above the grass tips while feeding, likely allowing feeding and predator detection to occur simultaneously (Redmond and Jenni 1986). The curlew bill is adapted to efficiently probe mudflats for invertebrate prey at staging sites and on wintering habitats (Stenzel et al. 1976).

1.4 Predators and mortality factors

The vulnerability of curlews to predators varies according to life stage: eggs, chicks, fledglings and adults. Terrestrial predators such as coyotes (*Canis latrans*), badgers (*Taxidea taxus*), red fox (*Vulpes vulpes*), weasels (*Mustela* spp.), skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*) and dogs (*Canis* spp.) are the most common predators of curlew eggs and chicks (Allen 1980; Redmond and Jenni 1986). Black-billed Magpies (*Pica pica*) may also be important predators of eggs (Allen 1980). Gopher snakes (*Pituophus catenifer*) were observed depredating a curlew nest in Colorado (Kingery and Kingery 1995). Chicks are also taken by a variety of avian predators, including the Swainson's Hawk (*Buteo swainsoni*), Ferruginous Hawk (*Buteo regalis*), Great Horned Owl (*Bubo virginianus*), and Black-billed Magpies (Allen 1980; Redmond and Jenni 1986). In Idaho, raptors were responsible for 73% of all mortality in young birds (Redmond and Jenni 1986). Other factors influencing chick mortality include starvation, excessive heat or cold, and the loss of parents due to wandering, abandonment or predation (Redmond and Jenni 1986). There is high pre-fledgling mortality in curlews and it is uncommon for a pair to fledge more than 2 young (Allen 1980).

Fledglings and adults are not likely regularly taken by predators. Few records exist of raptors preying upon fledglings and most adult mortality can be attributed directly to humans and human induced disturbance, including shootings (Redmond and Jenni 1986).

Fatal collisions between fledglings and vehicles, and man-made structures have been recorded (Allen 1980; Redmond and Jenni 1986). Grazing livestock including cattle and particularly sheep are responsible for trampled nests (Redmond et al. 1982; Bicak et al. 1982; Timken 1969). Some chemicals may cause mortality. Blus et al. (1985) describe the mortality of one adult curlew through organochloride poisoning, as well as egg thinning due to DDE residues. These chemicals are still used in some areas where the birds winter. Known parasites include some Mallophaga ectoparasites, and helminth endoparasites (Butler and Pfaffenberger 1981). Aspergillosis caused the death of one curlew chick in Idaho (Redmond and Jenni 1982).

1.5 Habitat preferences

Previous studies have found that curlews use expansive, open, level to gently rolling grasslands with short and/or mixed grass prairie (Bicak et al. 1982; Cochran and Anderson 1987; Pampush and Anthony 1993). Short-grass habitats include a variety of grasses that are short and can tolerate drought conditions. Mixed-grass gets its name from the predominance of both short and mid-height grasses. Long-billed Curlews have been recorded breeding on native short and mixed-grass prairie and on tame pastures (McCallum et al. 1977; Bicak et al. 1982; Cochran and Anderson 1987). Curlews rarely nest in hayland, cropland, fallow or stubble fields (Cochran and Anderson 1987; McCallum et al. 1977; Renaud 1980). Birds appear to forage in all habitat types during the breeding season (Allen 1980; Pampush and Anthony 1993). However, curlews will not use areas of extensive cultivation (Renaud 1980).

Differences in apparent habitat selection by curlews between studies seems to at least partly result from differences in local vegetation structure and habitat availability. Allen (1980) studied breeding birds in cropland and shrub-steppe (treeless plains containing both grasses and shrubs) habitats in Washington. She found that nesting preferentially occurred in areas dominated by downy brome (*Bromus tectorum*) and Sandberg's bluegrass (*Poa sandbergii*); with mean vegetation heights less than 20 cm; and approximately 24% coverage by live grasses and 69% coverage by dead grasses.

In Idaho, Redmond et al. (1982; 1986) investigated the use of short-grass pasture, tame pasture, and cropland habitats. Curlews preferred areas of short (<10 cm), recently grazed vegetation for nesting and foraging. However, when vegetation was dense due to excessive precipitation, they traveled up to 10 km to forage in areas with sparse vegetation.

In Wyoming, Cochran and Anderson (1987) looked at curlews in an area with short-grass hayland, short-grass pasture, tame hayland, tame pasture, and woodlands. The birds preferred irrigated native grass hayland and pasture over tame hayland and pasture. Curlews nested in hummocky areas that had lower mean grass percent cover, higher mean percent forb cover, and were drier than unused areas.

In Oregon where curlews had the choice of native short-grass pasture, tame short-grass, tame hayland, shrub-steppe, and cropland, they preferred to nest in areas of downy brome and Sandberg's bluegrass and avoided areas with shrubs or dense forbs (Pampush and Anthony 1993). Compared to non-nest areas, nest areas contained shorter vegetation, vegetation with less height variation, and higher vertical density in the 25-50 cm interval. Curlews foraged in fallow fields and tame hayland only if the vegetation was <30 cm tall.

Curlew habitat preferences are thought to change over the course of the breeding season. For example, nesting areas with shorter vegetation may be selected, but after chicks hatch, broods may shift to areas with different vegetation structure. During a year with abundant precipitation in Idaho, chicks moved to areas of less dense vegetation (Redmond et al. 1986).

The amount of available, suitable habitat may also influence habitat selection. European curlews (*Numenius arquata*) have a variable territory size depending on the spatial distribution of grasslands, such that they established larger territories in farmland than in areas of grassland (Berg 1992). Published values for territory or home range sizes of Long-billed Curlews are variable. In Idaho, territory size averaged about 14 ha in areas with dense populations. There was typically an unoccupied buffer zone of 300-500 m around the edge of suitable habitat (Redmond et al. 1981). In southeastern Washington, where the topography was open and flat with lower plant species diversity, territories were larger (20 ha); whereas in habitats with diverse topography, territories were smaller (6 to 8 ha; Allen 1980). In Saskatchewan, the only existing information regarding area of use comes from the record of one pair of adults with a brood having traveled 6.5 km from the nest site within six days of hatching (Sadler and Maher 1976).

There may be a relationship between proximity to water and habitat selection by curlews (McCallum et al. 1977; Cochran and Anderson 1987). In southeastern Colorado, 68% of observations (n= 63) occurred within approximately 400 m of standing water (McCallum et al. 1977). The presence of water within territories of European Curlews was more prevalent (63.8%) than in non-territories (29.8%; Berg 1992). Due to their site-fidelity, Long-billed Curlews may re-use areas regardless of the disappearance of previously existent wetlands.

Previous studies suggest that moderate livestock grazing is compatible with the maintenance of preferred curlew habitat. This is plausible because grazing produces the preferred short vegetation. Bicak et al. (1982) found curlew presence to be significantly correlated with spring and fall grazing intensity and significantly negatively correlated with vegetation height. They recommended that grazing should occur prior to nesting, so as to provide preferred vegetation heights and lessen the direct interaction with livestock. Some nest losses do occur as a result of livestock trampling. Heavy grazing may be detrimental because trampling could potentially cause significant nest loss (Redmond and Jenni 1982; Bicak et al. 1982).

1.6 Population trends

Long-billed Curlews were once abundant over most of the short-grass and mixed-grass prairie in the United States and southern Canada. Some settlers recalled the skies darkening in the 1800s as countless curlews flew overhead (Bent 1929). However, by the early 1900s curlew numbers declined drastically. Lawrence Potter, a naturalist from near Eastend, SK, reported in 1930 that "25 years ago, the Long-billed Curlew swarmed everywhere, today it has become a rarity" (Renaud 1980).

The historical decline of the Long-billed Curlew throughout its range is thought to have been primarily due to over-hunting coupled with extensive habitat loss. Curlews were shot by both sport and market hunters, for food or for their wings respectively (Bent 1929, Allen 1980, De Smet 1992). One curlew wing reportedly sold for 74 cents in 1900 because the wings were used to decorate women's hats (Allen 1980). Hunters took advantage of the curlew's nature to mob intruders and circle around wounded conspecifics (Allen 1980). In 1917, the Migratory Birds Convention Act and Regulations afforded protection from hunting to curlews and other migratory birds. This has been credited with saving the curlew from probable extinction (De Smet 1992).

However, arguably the single greatest factor in the historical decline in curlew populations has been the loss of habitat as a result of the conversion of native prairie to cropland and urban expansion (Hill 1998). Breeding habitat for curlews was destroyed when most native prairie was plowed for crop production in the early 1900's (Yocum 1956; Pampush and Anthony 1993). Bent (1929) noted, "The last of the great open prairies are rapidly disappearing and with them are going the curlews." In Saskatchewan, an estimated 84% of native grasslands in the Moist-Mixed-Grassland Ecoregion and 69% in the Mixed-Grassland Ecoregion have been lost to cultivation (Hammermeister et al. 2001).

Habitat loss continues to be a problem for the provincial curlew population. An estimated 24% of Saskatchewan's remaining native grasslands are at medium to high risk of being broken (Hammermeister et al. 2001; Saunders, in review). Habitat degradation due to fragmentation, invasion of exotic species, industrial development, and overgrazing, is potentially problematic for many prairie species including curlews. Decreases in wild fire occurrence and frequency may also have negative impacts over the long term, as fires previously would have killed most shrubs and created more open and favorable habitat (Allen 1980; Pampush and Anthony 1993).

Loss and degradation of habitat on their wintering grounds may also contribute to population declines (Hill 1998; De Smet 1992). Taken together, the factors contributing to the population decline are exacerbated by the species' low productivity and conservative breeding strategy (De Smet 1992; Redmond and Jenni 1986; Hill 1998).

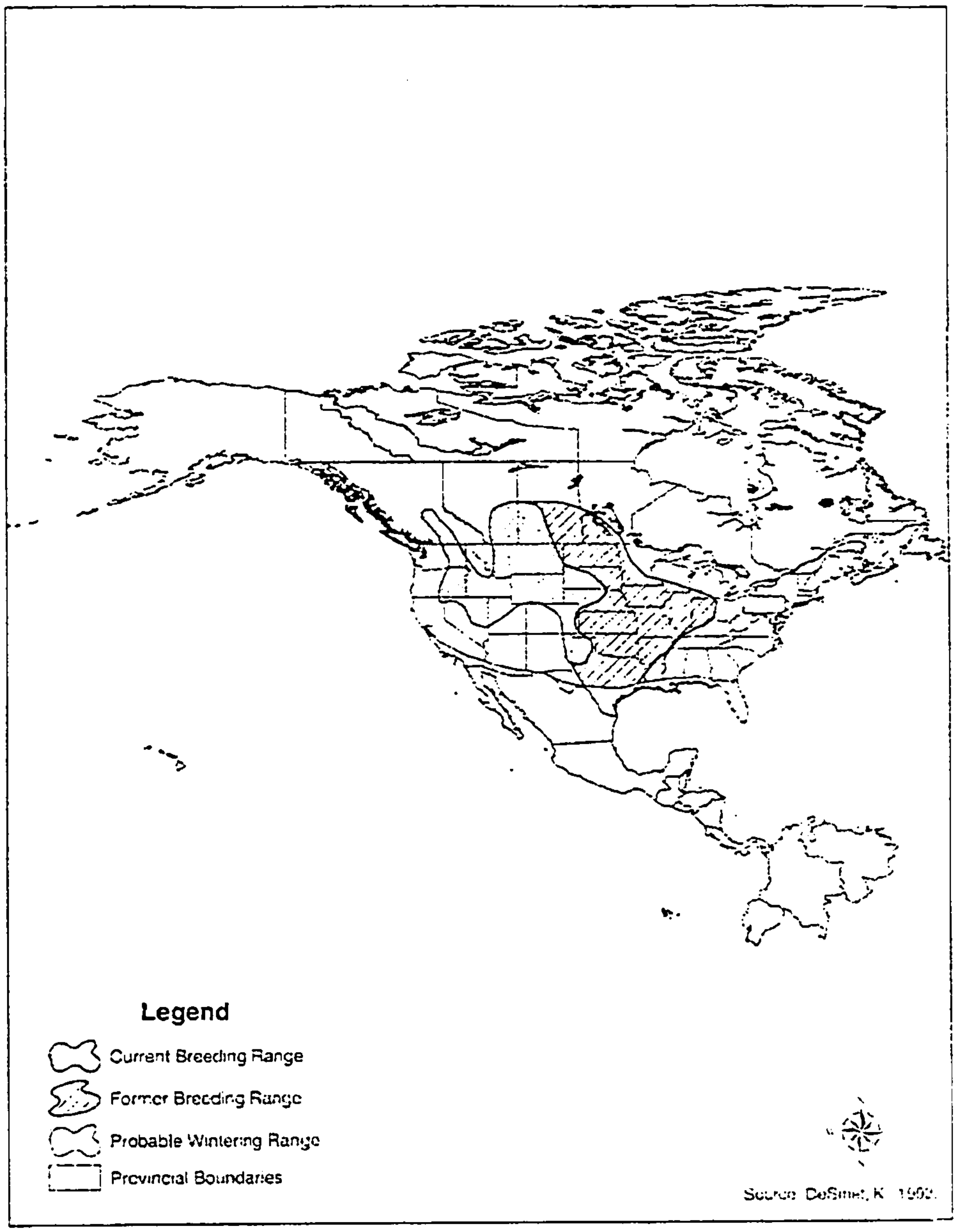
1.7 Current range and status

Long-billed Curlews have been extirpated in many areas of their historic range, including southern Manitoba, Michigan, Iowa, Minnesota, Wisconsin, Illinois, and eastern Nebraska (Allen 1980; Hill 1998). While it is unlikely that curlews ever bred in southeastern Saskatchewan in the numbers associated with the southwestern part of the province, they are now absent altogether from this former part of their range (Renaud 1980).

In Canada, curlews currently breed in southwestern Saskatchewan, southern Alberta, and in pockets of southern interior British Columbia. In the United States, curlews occur on grassland habitats in North Dakota, South Dakota, Wyoming, Montana, Nebraska, Oklahoma, western Kansas, northern Texas, northern New Mexico, Colorado, Nevada, Idaho, central Utah, northeastern California, Oregon, and Washington (Allen 1980; De Smet 1992; Hill 1998; Saunders, in review; Fig.1.0).

The curlews' wintering range is not nearly as well understood, but it is considered likely that curlews which breed in Canada winter in California, Texas, southern Louisiana, South Carolina, southern Florida, Mexico, Central America, and parts of South America (Allen 1980; Hill 1998; McNeil et al. 1985).

Species range contractions are often coupled with an overall population decline. This correlation cannot be made with certainty in the case of curlews given that there are few data on population sizes across North America. However, the limited available data provides the impression that curlew numbers are likely declining. Reported numbers in south-central Saskatchewan have



Source: DeSmet, K. 1992.

Figure 1.0 Breeding and wintering range of Long-billed Curlews in North America declined along the northern and eastern limits of the species' range since 1950 (Renaud 1980). Breeding Bird Survey (BBS) data indicate a continental decline of 2.0% annually between 1980 and 1996 (p= 0.10; n= 186 routes; Sauer et al. 1997; Hill 1998).

In 1992, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed the Long-billed Curlew as 'Vulnerable' despite the recommendation by the status report author that it be listed as 'Threatened' (De Smet 1992). This listing was assigned due to insufficient evidence documenting a decline in numbers, despite historical population declines and breeding range contraction. Since the species was listed, significant amounts of native grassland in Saskatchewan have been cultivated and/or degraded. In 2002, a mandatory review of the status of the Long-billed Curlew was undertaken by COSEWIC. This resulted in the birds being listed as a species of 'Special Concern' under the federal Species at Risk Act (Saunders, in review). Alberta and British Columbia have placed curlews on their Blue Lists indicating that the species may be at risk in those provinces (Hill 1998; Cannings 1999). Saskatchewan intends to list the curlew as 'Vulnerable' under the provincial Wildlife Act (P. James, pers. comm.).

The only attempt to estimate the size of the Saskatchewan curlew population was undertaken by the Canadian Wildlife Service in the late 1980s. Based on a survey of 5% of the townships within the curlew's range, the overall population size was estimated to be 1,700 pairs (A.R. Smith, pers. comm.). However, this is potentially an overestimate given that the townships surveyed had lesser amounts of cultivated land within them. Combined with the ongoing loss and degradation of native grasslands in Saskatchewan, the actual provincial population could be lower than the estimate. Our lack of clear knowledge regarding their ability to use other types of habitat also makes it difficult to determine the status of curlew populations.

1.8 Theses objectives and hypotheses

Despite its size and conspicuous nature, few comprehensive studies of the Long-billed Curlew have been undertaken. In Washington, Allen (1980) documented curlew ecology and behaviour. A multi-year study in Idaho investigated breeding density, clutch size, reproductive success, reproductive tactics, adult survival, and diet (Redmond and Jenni 1982; Bicak et al. 1982; Redmond and Jenni 1986). Pampush and Anthony (1993) evaluated habitat use, nest-site selection, and nest success in Oregon. There are few published Canadian accounts on the ecology, population status, or migration of curlews (Dickson and Beyersbergen 1998). This study aims to improve our knowledge regarding the Saskatchewan population. An improved knowledge of the population and its habitat requirements will help clarify the provincial status of this species and, should it be required, form a strong basis for conservation action for curlews in Saskatchewan.

Objective 1: To determine an appropriate large-scale census technique. To-date, upland shorebird census techniques have been mostly visual in nature (Redmond et al. 1981). However, playbacks of species' calls for call response surveys are effective at detecting some species of birds in the field. For example, Bogner and Baldasarre (2002) found call response surveys to be an effective sampling tool for Least Bitterns (*Ixobrychus exilis*). Despite studies such as this, a simultaneous comparison of this method with a traditional observation method for curlew detection has not been done. Redmond et al. (1981) found the density of curlews breeding in an area was reliably estimated by a modified Finnish line transect method. However, this method is typically applied to smaller study areas. I compared the effectiveness of a traditional five-minute point count survey method with that of a call response method for a large number of sampling points. I predicted call playbacks would be a more effective survey technique for curlews, given their extremely vocal and aggressive nature.

Objective 2. To determine Long-billed Curlew habitat use in Saskatchewan. In particular the seasonal use of native grassland, tame grassland, tame hayland, and cropland ecosystems in southwestern Saskatchewan. The importance of each to the provincial population is not known. I predicted that curlews would prefer native prairie and avoid cropland areas. I anticipated a shift in habitat use would occur as the breeding season progressed due to the distinct requirements of broods. I also investigated smaller-scale influences on curlew habitat selection. Habitat measurements were taken in order to identify variables associated with the presence of curlews. I expected curlews to prefer habitats with shorter vegetation and greater amounts of native or tame grass present. Because habitat selection typically differs for adult and young birds, I employed radio-telemetry to investigate the habitat use of curlew chicks before fledging. I predicted chicks would use areas with higher prey densities and proximate to wetlands.

Objective 3. To evaluate the relationship between presence or absence of curlews and the proximity of wetlands during various stages of the breeding season. Long-billed Curlews have been observed using habitat in close proximity to water, yet the importance of wetlands to curlews has not been examined (McCallum et al. 1977; Cochran and Anderson 1987). The existence of a correlation between curlews and water has potential implications for management recommendations. I predicted curlews would select habitats with nearby wetlands, particularly during brood rearing.

Obj*ective 4.* To generate a probability surface predicting areas of probable curlew occurrence in southern Saskatchewan by integrating survey and habitat selection data with Geographical Information Systems (GIS) satellite vegetation cover maps and data layers. The intent was to produce a probability surface to identify areas with increased probability for curlew occurrence for use in population status and management recommendations. I predicted a non-random distribution throughout the species' range such that the probability of curlew occurrence would increase in areas of primarily grassland habitat and decrease in extensively cultivated areas.

2. METHODS

2.1 Study area

My study was conducted within an 8000 km^2 area north of Maple Creek, SK and south of the South Saskatchewan River, between about *N* 49° 54` to *N* 50° 56`, and *W* 109° 10` to *W* 109° 57` (Fig. 2.1). This region is characterized by mixed grassland and is the driest area of the province (Saskatchewan Environment, Ecoregions Map 1998). The mean total annual precipitation for Leader, SK (a town in the northern part of the study area) is 352 mm, and the mean July temperature is 18.9 C. There is a notable absence of native trees and scarcity of wetlands and permanent water bodies in the area. The region contains various landscapes including level, glacial lake plains; dune-covered, sandhill areas; hilly pothole country; and rolling expanses of native prairie. Soil types generally vary from sandy to sandy-loam.

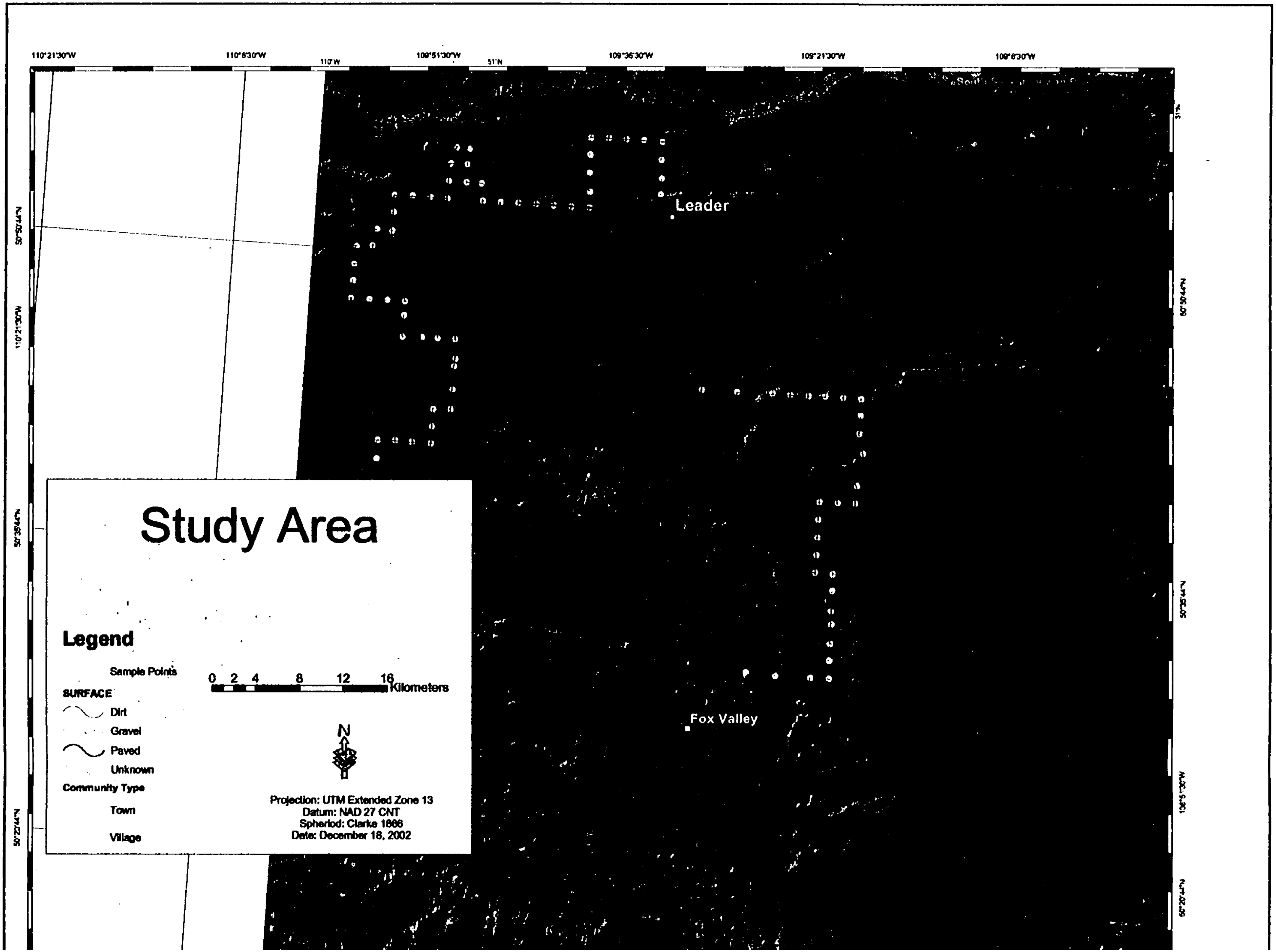
Typical native grasses include wheatgrasses (*Agropyron* spp.), speargrasses (*Stipa* spp.), and blue grama grass (*Bouteloua gracilus*), which is the dominant species during drought conditions or under high grazing pressure. Shrub communities composed of snowberry (*Symphoricarpos albus*) and wolf willow (*Elaeagnus commutata*) occur in areas with adequate soil moisture. Aspen (*Populus tremuloides*) is only found in valley bottoms and near sandhills. Mammals common in this region include pronghorn antelope (*Antilocapra americana*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), coyote, and Richardson's ground squirrel (*Spermophilus richardsonii*). Characteristic birds aside from curlews include Ferruginous Hawk, Western Meadowlark (*Sturnilla neglecta*), Burrowing Owl (*Athene cunicularia*), and Sprague's Pipit (*Anthus spragueii*).

More than half of the study area is cultivated, with the remainder used for livestock grazing on native or introduced grasses. Cereals are the main crop, but feed grains, forages and oilseeds are also grown (Saskatchewan Environment, Ecoregions Map 1998).

I selected this area for my study because it contains approximately one-third of the curlew's current range in the province and it has a suitable mosaic of rangeland and cropland, which enabled me to undertake an analysis of habitat preferences.

2.2 Survey methods

Within the study area, three survey routes were placed along various road networks to census each habitat type in relation to its relative abundance on the landscape. Point counts were undertaken every 1600 m (approximately one mile) at 200 sampling points along the survey routes (Cochran and Anderson 1987; Fig. 2.1). The spacing of sample points ensured independence of sampling. Each sampling point had a radius of 600 m, which was determined through preliminary testing to be the maximum radius allowing optimal detection of curlews. These noisy, conspicuous birds are readily detected in open habitats while feeding, lounging, or calling (Redmond et al. 1981).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Sample Points
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Gravel
Paved
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Community Type
Town
Village
0 2 4 8 12 16 Kilometers
N
Projection: UTM Extended Zone 13
Datum: NAD 27 CNT
Spheriod: Clarke 1866
Date: December 18, 2002
Leader
Fox Valley
110°21'30"W
110°6'30"W
110°W
109°51'30"W
51°N
109°36'30"W
109°21'30"W
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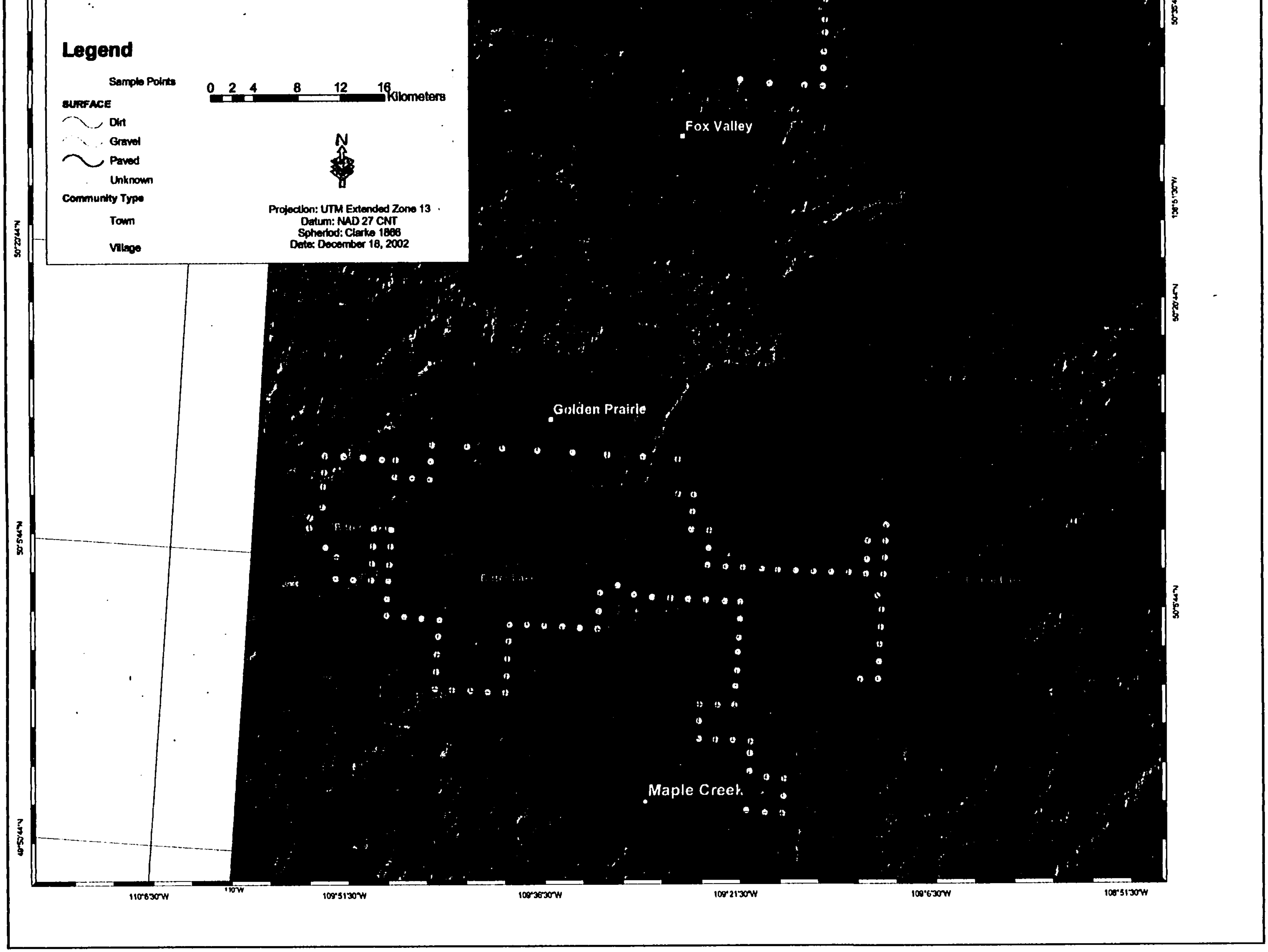
50°20'44"N
108°51'30"W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Projection: UTM Extended Zone 13
Datum: NAD 27 CNT
Spheriod: Clarke 1866
Date: December 18, 2002
Fox Valley
Golden Prairie
Maple Creek
50°22'44"N
50°5'44"N
49°52'44"N
50°35'44"N
108°51'30"W
50°20'44"N
50°5'44"N
110°6'30"W
110°W
109°51'30"W
109°36'30"W
109°21'30"W
109°6'30"W
108°51'30"W

The majority of observations were made using 8 x 40 Bushnell binoculars and a variable 15-60 spotting scope. At each sampling point, I recorded the number of Long-billed Curlews observed, along with habitat type, location, temperature, wind speed, precipitation, proximity to water, and behavioural information. Birds in flight were classified as using the habitat over which they were flying.

My surveys were conducted from April 21-June 29, 1999 and April 25-June 27, 2000, in order to assess potential changes in curlew habitat use throughout the summer. The census period occurred during three major time periods affiliated with the breeding cycle: pre-lay (when curlews return, defend their territories, attract mates, and initiate nesting); incubation (when adults incubate eggs); and post-hatch (the time between chick hatching and fledging; Allen 1980; Pampush and Anthony 1993). Each sampling point was censused on three separate occasions, separated by at least 16 days. I varied the times of day and order in which sampling points were visited to minimize sampling bias. When weather conditions impeded the detection of birds (i.e. rain, wind greater than 20 km/h, and temperatures above 25 C), surveys were halted.

I classified the area within the sampling points into seven habitat categories including: native prairie, tame pasture (typically crested wheatgrass monocultures), stubble, fallow, tame hay (seeded grasses not grazed but cut for use as hay), fall/winter crop, and spring/summer crop. The average habitat composition within the sampling points was approximately 30% native prairie (NP), 30% tame pasture (TP), and 40% cultivated land.

From survey data collected during the pre-lay and post-hatch periods in 1999 and 2000, I used a G-test (or log-likelihood ratio test) to determine whether the distribution of curlews was as expected based on the availability of each habitat type within the sampling points. Chi-square tests were subsequently performed for each habitat to assess whether each was being used significantly different than expected (James and Verbeek 1984). Expected values were calculated by multiplying the total number of curlews detected per time period and the overall percentage of each habitat available within the sampling points. All statistical analyses were performed using Statistica (version 6.0, StatSoft. Inc., Oklahoma, USA).

2.2.1 1999 survey

In 1999, I conducted trials consisting of both passive listening and call response periods to compare the effectiveness of these census methods for detecting Long-billed Curlews. Five minutes of listening were followed by the broadcast of a 60 second segment of tape of curlew vocalizations, using a predator caller (Model 512, Johnny Stewart Wildlife Calls, Iowa, USA). The "wheet-wheet-wheet, curlee-curlee-curluoooo" call was used. This was followed by one minute of listening.

A chi-square test was employed to compare the effectiveness of the five-minute listening period and call-response method to census curlews in the field.

2.2.2 2000 survey

The survey protocol of using call playbacks was not repeated in 2000. I only employed the five-minute listening period. Otherwise, the census was repeated at the same sampling points along the same survey routes to collect data, which allowed for enhanced assessment of habitat preferences and annual differences.

T-tests were used to determine whether there were any significant differences in the number of birds detected in 1999 and 2000.

2.3 Habitat Measurements

In July 2000, I measured habitat parameters to identify the key habitat requirements of curlews. Vegetation structure and general composition was measured in each field within the 600 m radius at every third sampling point along the survey route (n= 67).

In each field, I took five samples using a 0.5m x 0.5m quadrat placed on the ground. One quadrat was situated every 50 m along a transect, which was positioned perpendicular to the fence-line. I used a Wiens pole to measure vegetation height and estimate vegetation density (Wiens 1973). This device measures vegetation touching a 1 cm radius vertical pole at 10 cm intervals up to 100 cm. In each quadrat, I recorded the number of touches of either live vegetation (current year's growth) or dead vegetation (previous year's growth) for each 10 cm interval. The total number of touches was translated into a measure of vertical density (Wiens 1973).

I estimated the percentage areal cover of bare ground, grass, forbs, shrubs, dead litter, and *Selaginella densa* within each quadrat (Pampush and Anthony 1993; S. K. Davis, pers. comm.; Table 2.1). The type of shrub present and distance to nearest shrub was recorded. The litter depth was measured (mm) near the center of the quadrat using a standard ruler.

The collection of habitat measurements and curlew occurrence data did not overlap precisely in time. The habitat measurements were taken in July, while the surveys were completed in April, May, and June. However, due to the site-fidelity of these birds, the measurements of vegetation structure can be extrapolated to times of observed curlew occurrences without difficulty.

To improve normality, all percentage data was arcsine/square-root transformed and vertical density data were log transformed (Sokal and Rohlf 1981). Curlew abundance data were converted to presence or absence data. Then, I used logistic regression analyses to assess the relationship between habitat variables and curlew occurrence at sampling points.

All logistic regression models developed for this study were fitted using a maximum likelihood method and a forward stepwise procedure was used to select the final variables (Jongman et al. 1995). Cohen's kappa was calculated to assess the effectiveness of the models to correctly classify presence or absence over that by chance (Titus et al. 1984; Fielding and Bell 1997).

Table 2.1 Description of habitat variables measured

VARIABLE	DESCRIPTION
Vertical density of live vegetation	Number of touches by live plants within 10 cm intervals along a Wiens pole (Wiens 1973)
Vertical density of dead vegetation	Number of touches by dead plants within 10 cm intervals along a Wiens pole (Wiens 1973)
Percent bare ground	Estimate of percentage areal cover of bare ground within 0.5 x 0.5 m quadrat
Percent forb	Estimate of percentage areal cover of forbs within 0.5 x 0.5 m quadrat
Percent grass	Estimate of percentage areal cover of grass within 0.5 x 0.5 m quadrat
Percent *Selaginella*	Estimate of percentage areal cover of *Selaginella densa* within 0.5 x 0.5 m quadrat
Percent shrub	Estimate of percentage areal cover of shrubs within 0.5 x 0.5 m quadrat
Type of shrub	Shrubs less than 15 cm tall are categorized as dwarf and those taller than 15 cm are categorized as large within 0.5 x 0.5 m quadrat
Distance to nearest shrub	Measurement from the center of the quadrat to the nearest shrub within the field
Litter depth	Depth (mm) of unattached or decaying litter

2.4 Wetlands

In 1999, I frequently observed curlews in habitats close to wetlands, yet the importance of these habitat features has not been investigated directly. Consequently, I evaluated curlew use of wetlands during the breeding season of 2000. I also noted the location and characteristics of staging sites.

During the second week of August 2000, I recorded the number and type of each wetland (wet or dry) present within the 600 m radius of each sampling point. I used Stewart and Kantrud's (1971) wetland classification system for natural ponds and lakes in the glaciated prairie region. Wetland vegetation in the prairie region was grouped into zones each characterized by a different community structure and a distinct group of plant species (Stewart and Kantrud 1971). The vegetational zone occurring in the central part distinguished each class if it occupied 5 percent or more of the total wetland class being classified (Table 2.2). Subclasses, within the major classes of wetlands, are based on differences in plant communities within the zones that are correlated with variations in average salinity of surface water (Table 2.3). Cover types represent differences in the spatial relation of emergent cover to open water or exposed bottom soil (Stewart and Kantrud 1971). Cover interspersion in natural ponds and lakes can be one of four types (Table 2.4).

This system was used to classify all wetlands within the 600 m radius of all 200 sampling points (Stewart and Kantrud 1971). Since wetlands were recorded as present whether they were currently wet or dry, an investigation was possible

Table 2.2 Description of wetland classes (Stewart and Kantrud 1971)

WETLAND CLASS NUMBER	WETLAND CLASS DESCRIPTION	DOMINANT ZONE	PERIPHERAL ZONE(S)
I	Ephemeral ponds	Wetland-low prairie	None
II	Temporary ponds	Wet-meadow	Low-prairie
III	Seasonal ponds and lakes	Shallow-marsh	Wet-meadow and low-prairie
IV	Semipermanent ponds and lakes	Deep-marsh	Shallow-marsh, wet-meadow and low-prairie
V	Permanent ponds and lakes	Permanent-open water	Deep-marsh, wet-meadow, and low-prairie
VI	Alkali ponds and lakes	Intermittent alkali	Shallow-marsh, wet-meadow, and low-prairie
VII	Fen (alkaline) bog	Fen	Wet-meadow and low-prairie

Table 2.3 Subclass designations for wetland classification (Stewart and Kantrud 1971)

SUBCLASS	DESCRIPTION
A	Fresh
B	Slightly brackish
C	Moderately brackish
D	Brackish
E	Subsaline

Table 2.4 Cover types used in wetland classification (Stewart and Kantrud 1971)

COVER TYPE	DESCRIPTION
1	Closed stands of emergent vegetation with open water or bare soil covering less than 5 percent of the wetland area.
2	Open water or bare soil covering 5 to 95 percent of the wetland area, with scattered dense patches or diffuse open stands of emergent cover.
3	Central expanses of open water or bare soil (comprising more than 5 percent of the wetland area) surrounded by peripheral bands of emergent cover averaging 2 m or more in width.
4	Open water or bare soil covers more than 95 percent of the wetland area.

for both the 1999 and 2000 breeding seasons. I investigated the relationship between curlew presence and the number or class of wetlands present through logistic regression analyses. I also employed multiple regression analysis to determine whether certain classes of wetlands were related to curlew abundance for only those sampling points containing curlews.

2.5 Radio telemetry

To quantify the importance of each habitat type during the breeding season, I attached radio transmitters to seven juveniles approximately two weeks old in June and July 2000 (Table 2.5). Transmitters with a 24 cm whip-like antenna (Model RI–2B, Holohil Systems Ltd., Carp, ON) were affixed using an adjustable elastic necklace (Fig. 2.2). The units each weighed approximately 6 g, which is equivalent to about 2% of the body mass of the sampled chicks (mean mass= 296 g). The transmitters had a lifespan of approximately three months. The necklace was designed to eventually degrade and fall off the bird. Each transmitter produced a unique signal at frequencies between 172.643 and 172.843 MHz. This protocol was approved by the University of Regina President's Committee on Animal Care.

Juveniles were caught by hand in pastures or road-sides. The presence of chicks was often apparent based on parental behaviour. I scanned the area with binoculars to fix the chicks' location, and then ran quickly to catch them. Measurements were made using Vernier calipers and the necklace was fitted around the base of the neck. Within 15 minutes, radio-tagged chicks were

Table 2.5 Measurements of radio-tagged Long-billed Curlew chicks

CHICK NUMBER	CAPTURE DATE (MM/DD/YR)	MASS (G)	TARSUS LENGTH (MM)	CULMEN LENGTH (MM)	WING LENGTH (MM)
1	07/13/2000	359	63.0	55.4	179
2	07/10/2000	300	62.2	44.8	152
3	06/30/2000	244	53.7	47.3	179
4	07/05/2000	239	51.9	35.7	113
5	07/02/2000	374	61.2	56.9	174
6	07/04/2000	269	60.1	57.2	206
7	07/05/2000	285	61.9	47.9	205

Figure 2.2 Model RI-2B radio transmitter and adjustable elastic necklace (Holohil Systems Ltd., Ontario, Canada)

released at the site of capture. After a chick was radio-tagged, all efforts were made to not disturb it further.

Lotek receivers, model SRX-400, and 3-4 element Yagi antennas were used to detect transmitter signals. Tracking was usually done with the antenna directed out a window or from the roof of a truck. The portable receiver enabled me to walk into fields or along roadways in search of signals when necessary. The peak-null method was used to determine the location of the signal (Banks et al. 1975).

Each subject was located every 2-3 days. More frequent sampling was not possible due to the large size of the study area and the long distances between radio-tagged chicks. The precise location of each chick was determined using a handheld global positioning system (GPS) unit (eTrex Summit, Garmin Ltd. Kansas, USA), and then recorded and plotted on a map of the study area. Habitat type, date, time, weather, and behavioural information were also noted. Chicks were tracked for an average of 23 days. Typically, I followed them until they fledged and left the study area.

All telemetry data were entered into ArcView 3.2 and analyzed using Statistica 6.0. Data for chicks were grouped according to the number of available habitats in the area of their detection. The distance of movements of chicks with one available habitat type (n= 3) were compared to those of chicks with two or more available habitat types (n= 4) using a t-test.

2.6 Geographical Information Systems (GIS) and probability surface

Satellite imagery (Landsat), as well as various GIS data layers including soils data, and lake, river, and road buffers with 100 m, 200 m, 300 m, 400 m and 500 m intervals within my study area were provided by Saskatchewan Environment. A handheld GPS unit (eTrex Summit, Garmin Ltd., Kansas, USA) was used to determine exact locations of my sampling points.

GIS was used to identify and delineate native prairie, tame pasture, and cropland areas throughout the potential range of the species in Saskatchewan. ArcView 3.2 was used to pool these data in a spatial data table. Logistic regression analyses were performed to generate a model including spatial data variables to explain curlew presence and absence.

For the construction of a probability surface to be extrapolated across southern Saskatchewan, only large-scale, spatial data variables were considered. My fine-scale habitat measurements were not included in the models, which are intended for application across areas for which comparable measurements do not exist. Therefore, the spatial data variables and the logistic regression model which best predicted curlew occurrence were used to create a probability surface to identify areas with increased probability for curlew occurrence across southern Saskatchewan. GIS probability surfaces were produced using Arc-INFO.

The probability surface provides a means of assessing possible curlew numbers in Saskatchewan, and could subsequently be used to provide estimates of the population status.

3. RESULTS

3.1 Breeding chronology

3.1.1 1999

I first observed curlews in my study area on 8 April 1999. Only a few birds were initially present, but most birds returned within one week of this date.

I only found one nest and it was located in a crop field. The nest diameter was 220 mm and it was lined with straw. The average width of eggs (n= 4) was 47.3 mm, length 62.4 mm, and mass 62.8 g. The four eggs hatched within six hours of one another. The average mass of the newly hatched chicks was 53.7 g, wing length 20.4 mm, tarsus 44 mm, and culmen 22.2 mm.

Most juveniles were capable of flight by mid-July. In late July, a staging site with a maximum of 55 juvenile curlews was located in an alkali slough near Crane Lake (N 50E1', W 109E12'). I observed juvenile curlews probing the slough for invertebrate prey. My last observation for the year occurred on 4 August.

Within the study area, there appeared to be a relationship between the presence of wetlands and curlews. Approximately half (48%, n= 90) of the birds I detected were found in proximity to water (defined as within 600 m); however, only 27% of the sampling points were proximate to wetlands. Two areas with markedly high densities of curlews were located near Bitter Lake and Crane Lake.

3.1.2 2000

In 2000, the first curlews appeared in the study area on 11 April. Birds were often found on the same territories as in 1999. Of the 110 sites used by curlews in 1999, 80 (or 73%) were re-used in 2000.

One nest was discovered in 2000. It was in native grassland on the crest of a hill. The nest had a diameter of 201 mm and was lined with grass and straw. It was situated directly beside dry cow dung. There were some small rocks among the four eggs. Only the adult female was observed near the nest, perhaps indicating that the male may have died. I did not take measurements or return until post-hatch, to minimize the risk that the lone female would abandon the nest. All four eggs hatched, but the chicks were never found.

One young chick was caught late in the season near Burstall, SK, on 7 July. This chick was smaller than the newly hatched chicks measured in 1999 (mass 48 g, tarsus 29.4 mm, culmen 19.3 mm, and wing 24.0 mm). The discovery of a recently hatched chick at this late date suggests that the parents either delayed nesting or re-nested.

A flock of approximately 75 curlews and 35 Marbled Godwits (*Limosa fedoa*) was observed using the same staging site as in 1999. This group consisted mainly of juveniles and adult male curlews and godwits. One female curlew was noted. Birds were last seen on 5 August.

Long-billed Curlews and Marbled Godwits were sometimes found proximate to one another. On several occasions, when upset curlews were mobbing perceived predators (including me), neighbouring godwits would call and dive.

3.2 Survey results

Surveys were conducted during the pre-lay, incubation, and post-hatch periods of the breeding season. However, because there was substantial variation among pairs in apparent laying dates, I included only the pre-lay and post-hatch periods in my analyses. This reduces the chance of overlap between time periods and allows for a more rigorous assessment of the potential shift in the types of habitats used based on breeding chronology to be observed. This also allowed me to use the data collected during the incubation period as a "hold-out" data set to evaluate the predictive power of my logistic regression models.

Data on abundance and habitat use were analyzed using a modified chi-square test, the G-test (or log-likelihood ratio test). This was necessary because more than 20% of the values were less than five, and thus would not fit the assumptions of a chi-square test (Zar 1984). Chi-square tests were performed for each habitat type to assess whether each was being used significantly different than expected.

3.2.1 1999 survey results

3.2.1.1 Call-response trial results

During the pre-lay period in 1999, 200 curlews in total were detected. Of those, 174 were found during the five-minute listening period. During call- response surveys I heard or saw 26 previously undetected birds and 88 known birds for a total of 114. In my assessment of habitat use during the pre-lay period, I used the number of birds detected by both methods (n= 200).

During the post-hatch period in 1999, a total of 176 curlews were observed. During the five-minute listening period, 168 curlews were found. Call-response surveys revealed eight previously undetected birds and 63 known birds for a total of 71. Again, I used the total number of curlews found using both survey methods in post-hatch habitat investigations (n= 176).

More curlews were detected using the call-response method during the pre-lay period than the post-hatch, but still far fewer than with the five-minute listening method alone. On average, 91% of curlews were detected during the five-minute listening period, whereas only 49% of those curlews responded to call playbacks (Fig. 3.1). Call-response surveys alone detected an additional 9% of curlews that went undetected during the listening period.

For the analysis, I pooled survey data from the pre-lay and post-hatch periods because these data were not significantly different (t= 0.71, df= 400, p= 0.480). Based on pooled data, call response surveys were significantly less effective at detecting curlews than the five-minute listening period ($\chi^2 = -42.47$, df= 1, p= 0.0016). Thus, call response surveys were significantly less effective at detecting curlews than the five-minute listening period.

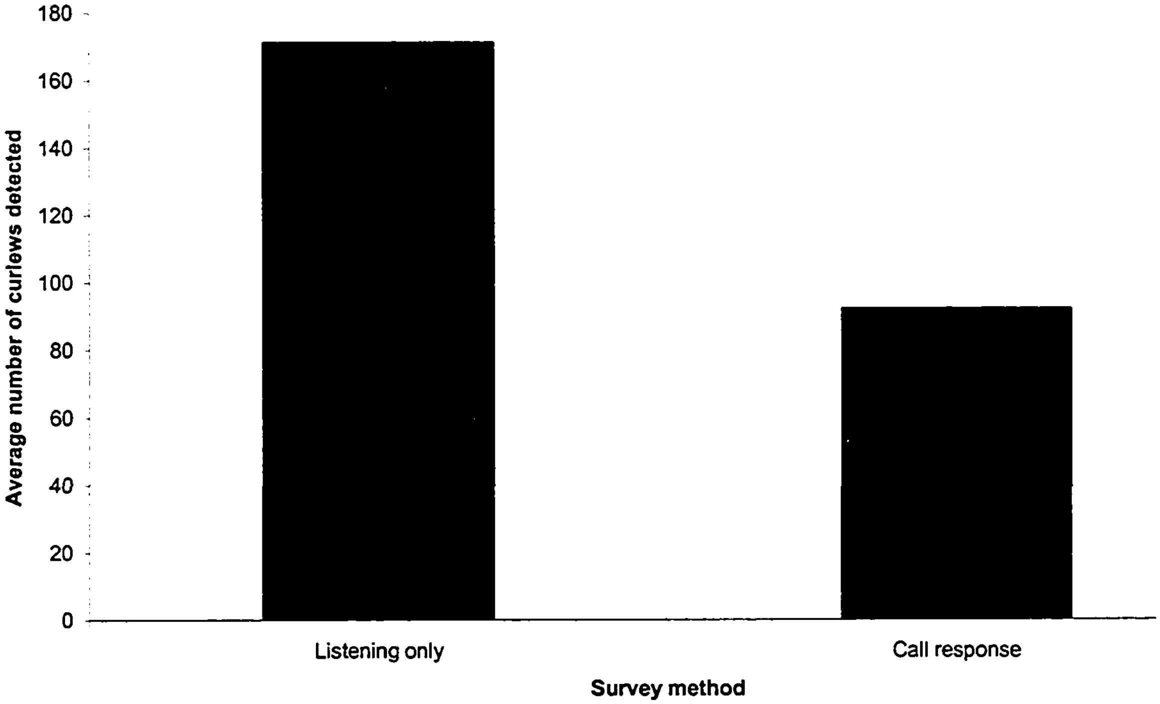


Figure 3.1 Average number of curlews detected during the five-minute listening period and during the playback call-response period in 1999

3.2.1.2 Pre-lay 1999

Curlew surveys during the pre-lay period were conducted from 21 – 27 April 1999. I observed a total of 200 curlews at the 200 sampling points. This can be converted to number of pairs using a formula generated from data for the European curlew: # pairs = 0.71 (# of Mean Individuals) + 0.10 (Grant et al. 2000). This formula produces an estimate of 142 pairs.

Within the sampling points, the habitat composition was approximately 34% native prairie, 29% tame pasture, 16% stubble, 11% fallow, 5% tame hay, and 5% fall/winter crop. Curlews were not distributed among habitats as expected based on habitat availability (Fig. 3.2) during the pre-lay period in 1999 ($G= 51.7$ $df= 5$, $p<0.001$).

During the pre-lay period, curlews occurred in areas of native prairie and fall/winter crop more often than expected based on the availability of those habitats and were found less often than expected in areas of stubble, fallow and tame hay. Tame pastures were used as expected based on availability (Table 3.1).

3.2.1.3 Post-hatch 1999

During post-hatch surveys, conducted from 10 – 19 June 1999, I located a total of 176 curlews.

The habitat composition at sampling points during this period was approximately 34% native prairie, 28% tame pasture, 13% stubble, 3% fallow, 5% tame hay, 5% fall/winter crop, and 12% spring/summer crop. The distribution

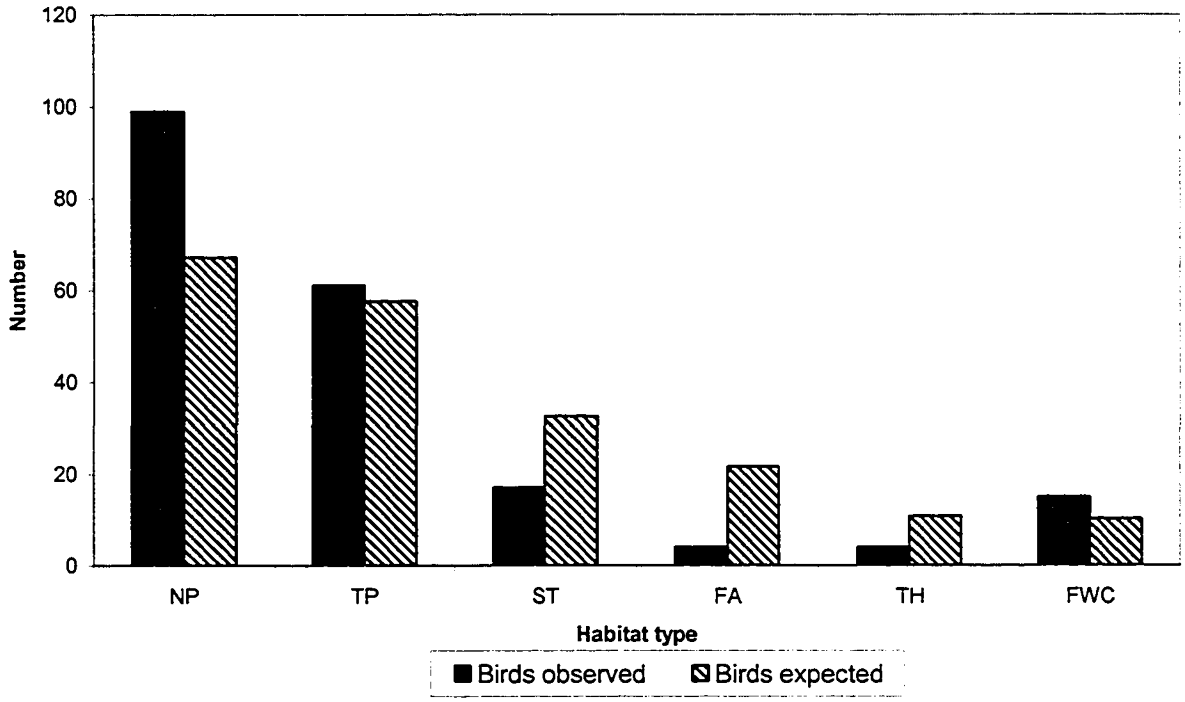


Figure 3.2 Number of curlews observed and expected in each habitat type during the 1999 pre-lay period
(NP= native prairie, TP= tame pasture, ST= stubble, FA= fallow, TH= tame hay, FWC= fall/winter crop)

Table 3.1 1999 pre-lay survey results of habitat types used

Habitat Type	Chi-square value	Significance	Direction
NP	30.10	*	+
TP	0.40	NS	+
ST	14.93	*	-
FA	28.68	*	-
TH	8.56	*	-
FWC	4.52	*	+

NP= native prairie, TP= tame pasture, ST= stubble, FA= fallow, TH= tame hay, FWC= fall/winter crop, *=significant at $p<0.05$, NS= not significant, + = positive relationship, - = negative relationship of curlews was not as expected based on habitat availability (G= 42.1, df= 6, p<0.001; Fig. 3.3).

During the post-hatch period, curlews were found more often than expected in areas of native prairie and spring/summer crop and less often than expected in areas of tame pasture, fallow, tame hay and fall/winter crop. Curlews occurred in stubble fields as expected based on the availability of that habitat (Table 3.2).

3.2.2 2000 survey results

3.2.2.1 Pre-lay 2000

In 2000, pre-lay surveys occurred from 25 April - 10 May. I conducted the surveys using only the five-minute listening period. The total number of curlews detected was 148. The estimated number of pairs was 105 (Grant et al. 2000).

At sampling points, the habitat composition was approximately 34% native prairie, 28% tame pasture, 21% stubble, 14% fallow, 2% tame hay, and 1% fall/winter crop. I found that curlews were distributed among habitats as expected based on habitat availability (Fig. 3.4) during the pre-lay period in 2000 (G= 7.8, df= 5, p<0.05).

Despite the G-test results, I subsequently performed chi-square tests to be consistent in the analyses conducted for each time period in both years. This analysis revealed that during the pre-lay period in 2000, areas of fallow and tame hay were used significantly less than expected based on habitat availability, while areas of native prairie, tame pasture, stubble, and fall/winter crop were being

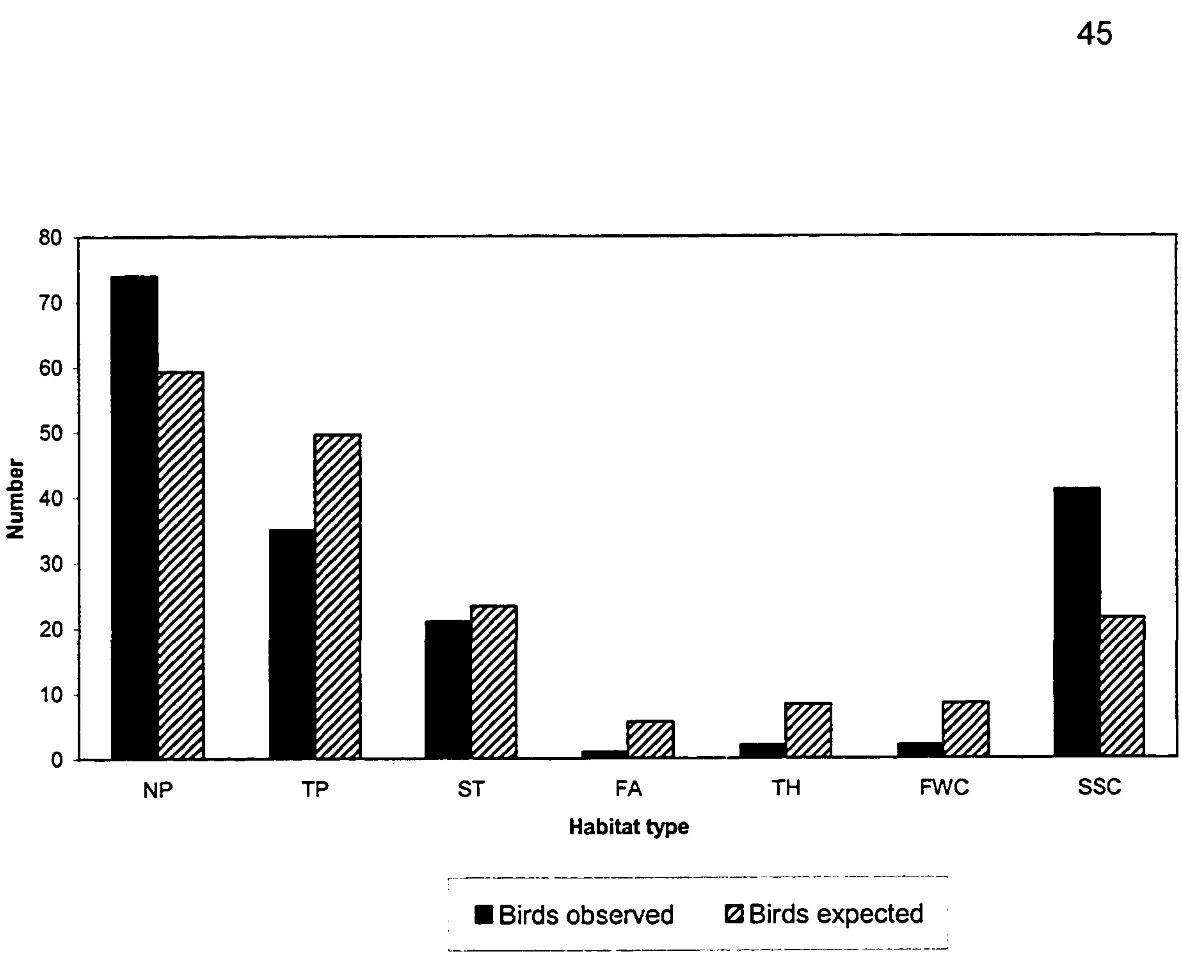


Figure 3.3 Number of curlews observed and expected in each habitat type during the 1999 post-hatch period
(NP= native prairie, TP= tame pasture, ST= stubble, FA= fallow, TH= tame hay, FWC= fall/winter crop, SSC= spring/summer crop)

Table 3.2 1999 post-hatch survey results of habitat types used

Habitat Type	Chi-square value	Significant	Direction
NP	7.69	*	+
TP	8.60	*	-
ST	0.45	NS	-
FA	7.56	*	-
TH	9.54	*	-
FWC	9.75	*	-
SSC	35.37	*	+

NP= native prairie, TP= tame pasture, ST= stubble, FA= fallow, TH= tame hay, FWC= fall/winter crop, SSC= spring/summer crop, *= significant at p<0.05, NS= not significant, + = positive relationship, - = negative relationship used as expected (Table 3.3). The G-test likely did not reflect these results due to the small proportion of curlews (15/148) that occurred in fallow and tame hay fields.

3.2.2.2 Post-hatch 2000

From 5 to 27 June 2000, I detected a total of 188 birds at the 200 sampling points.

During the post-hatch period in 2000, the habitat composition at sampling points was approximately 33% native prairie, 28% tame pasture, 13% stubble, 5% fallow, 3% tame hay, 1% fall/winter crop, and 17% spring/summer crop. The distribution of curlews was not as expected based on habitat availability (Fig. 3.5) during this period ($G= 42.1$, $df= 6$, $p<0.001$).

I found that curlews occurred in areas of spring/summer crop more than expected based on availability and less than expected in areas of fallow and stubble. Areas of native prairie, tame pasture, tame hay, and fall/winter crop were used as expected (Table 3.4).

3.2.3. Survey summary

Since the same sampling points were surveyed in 1999 and 2000, a comparison of annual differences was possible. However, I used a different sampling method between years as the call-response method was not used in 2000. To allow a direct and meaningful comparison of annual differences, the number of curlews detected from the call-response method was subtracted from

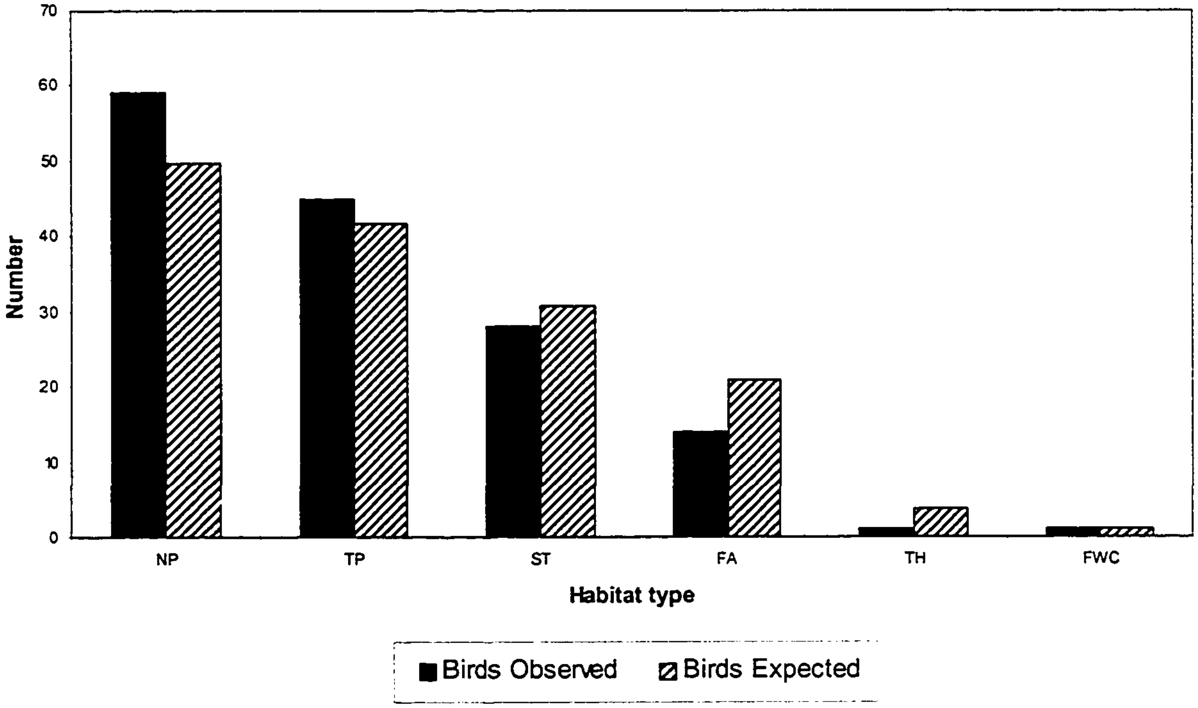


Figure 3.4 Number of curlews observed and expected in each habitat type during the 2000 pre-lay period
(NP= native prairie, TP= tame pasture, ST= stubble, FA= fallow, TH= tame hay, and FWC= fall/winter crop)

Table 3.3 2000 pre-lay survey results of habitat types used

Habitat Type	Chi-square value	Significance	Direction
NP	3.55	NS	+
TP	0.51	NS	+
ST	0.48	NS	-
FA	4.45	*	-
TH	3.94	*	-
FWC	0.07	NS	+

NP= native prairie, TP= tame pasture, ST= stubble, FA= fallow, TH= tame hay, FWC= fall/winter crop, *= significant at $p<0.05$, NS= not significant, + = positive relationship, - = negative relationship

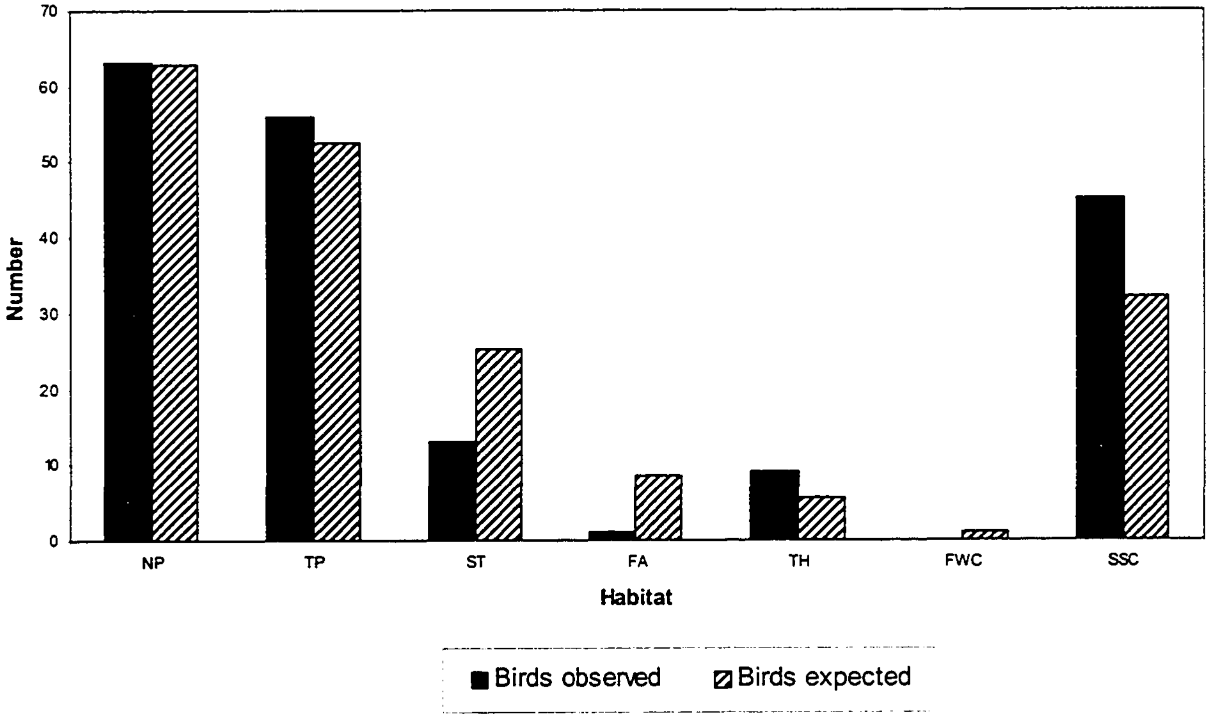


Figure 3.5 Number of curlews observed and expected in each habitat type during the 2000 post-hatch period
(NP= native prairie, TP= tame pasture, ST= stubble, FA= fallow, TH= tame hay, FWC= fall/winter crop, and SSC= spring/summer crop)

Table 3.4 2000 post-hatch survey results of habitat types used

Habitat Type	Chi-square value	Significant	Direction
NP	0.03	NS	+
TP	0.47	NS	+
ST	11.67	*	-
FA	13.43	*	-
TH	3.30	NS	+
FWC	2.00	NS	-
SSC	10.18	*	+

NP= native prairie, TP= tame pasture, ST= stubble, FA= fallow, TH= tame hay, FWC= fall/winter crop, SSC= spring/summer crop, *= significant at p<0.05, NS= not significant, + = positive relationship, - = negative relationship the total number of curlews for both periods in 1999. I found no significant annual difference in curlew numbers between the 1999 and 2000 pre-lay periods (t= 1.32, df= 400, p= 0.18) or the post-hatch periods (t= -0.34, df= 400, p= 0.73).

Generally, my survey data indicate that curlews occur less than expected based on habitat availability in areas of fallow, stubble and tame hay throughout the breeding season, and occurred more than expected in areas of spring/summer crop during the post-hatch period. Birds were found in tame pasture in the same proportion as expected relative to its abundance. In 1999, curlews were found significantly more often than expected in native prairie throughout the season (Table 3.5).

3.3. Habitat measurements

I entered eleven habitat variables into logistic regression analyses for the pre-lay and post-hatch periods in 2000. These included vertical density of live vegetation and dead vegetation in 10 cm height intervals, litter depth, type of shrubs present, the distance to the nearest shrub, and the percentage areal cover of grass, forbs, shrubs, bare ground, and *Selaginella*. Because these variables were measured at every third sampling point, these models are based on a subset (n= 67) of the total number of sampling points (n= 200).

3.3.1 Pre-lay 2000

Through logistic regression analyses, I found that three habitat variables were significant predictors of curlew occurrence during the pre-lay period. The vertical density of dead vegetation in the 0-10 cm and 10-20 cm intervals, and the estimated percentage areal cover of grass were both significantly related to curlew presence (Table 3.6). Specifically, occurrence was best predicted by increasing grass cover, increasing vertical density of dead vegetation from 0-10 cm high, and decreasing vertical density of dead vegetation from 10-20 cm high (Table 3.7).

The model correctly classified 76.3% of curlew absences (n= 28) and 67.9% of occurrences (n= 38). The Cohen's kappa statistic, calculated as per Titus et al. (1984), was 0.64 with a 95% confidence interval of 0.50 to 0.78. This is considered a good to excellent range for classification (Fielding and Bell 1997; Table 3.7), and means that the model classified occurrence 50 to 78% better than by chance alone.

The data collected during the incubation period were used as a "hold-out" data set to test the predictive power of the model. Using these data, the model correctly classified 72.2% of curlew absences and 85.0% of occurrences (n= 38).

3.3.2 Post-hatch 2000

For the 2000 post-hatch period, variables which significantly predicted curlew occurrence were the estimated percentage areal cover of grass, bare ground, and *Selaginella* (Table 3.8). The vertical density of dead vegetation in the 10-20 cm interval (p= 0.06) was not included in this model. Curlew occurrence was best predicted by increasing percentage areal cover of bare ground and grass, and decreasing cover of *Selaginella*.

Table 3.5 Differences between the number of curlews observed and expected using each habitat type during the 1999 and 2000 breeding seasons

Habitat type	Pre-lay 1999	Post-hatch 1999	Pre-lay 2000	Post-hatch 2000
NP	* (+)	* (+)	NS	NS
TP	NS	* (-)	NS	NS
ST	* (-)	NS	NS	* (-)
FA	* (-)	* (-)	* (-)	* (-)
TH	* (-)	* (-)	* (-)	NS
FWC	* (+)	* (-)	NS	NS
SSC	n/a	* (+)	n/a	* (+)

NP= native prairie, TP= tame pasture, ST= stubble, FA= fallow, TH= tame hay, FWC= fall/winter crop, SSC= spring/summer crop, *= significant at $p<0.05$, NS= not significant, (-)= negative relationship, (+)= positive relationship

Table 3.6 Habitat variables used in the logistic regression model for the 2000 pre-lay period (significant at $p<0.05$)

Variable	Wald Chi-square	P- value
Vertical density, dead vegetation, 0-10 cm	4.79	0.029
Vertical density, dead vegetation, 10-20 cm	5.62	0.018
Percentage areal cover of grass	4.27	0.039

The model including all three variables was highly significant for predicting the occurrence of curlews (Table 3.7). The model correctly classified 86.7% of curlew absences (n= 45) and 57.1% of occurrences (n= 21). Cohen's kappa statistic was 0.71 with a 95% confidence interval of 0.58 to 0.84. This is considered a good to excellent range for classification (Titus et al. 1984; Fielding and Bell 1997), and means that the model classified curlew occurrence 58 to 84% better than by chance alone.

The hold-out data was correctly classified 61.1% for curlew absences and 70.0% for occurrences (n= 38). Thus, the model is effective at predicting curlew occurrence.

3.4. Wetlands

Logistic regression analyses of the 1999 and 2000 data for both time periods indicate that none of the variables concerned with wetlands, including classes or total number, were significant predictors of curlew occurrence. However, the total number of wetlands had a strong positive correlation with curlew presence ($p = 0.06$) in the pre-lay 2000 period, and the wetland class VI, cover type 4 (alkali wetlands) was significant at $p < 0.10$ in the post-hatch 2000 period.

I employed multiple regression analyses to the data from areas with curlews present. For the 1999 pre-lay period only, curlew abundance significantly increased with the presence of wetlands of class I (ephemeral

Table 3.7 Logistic regression models including habitat variables that best predicted occurrence of curlews for the pre-lay and post-hatch periods in 2000

	Pre-lay 2000	Post-hatch 2000
Fitted Model for logit response	= -1.397+ 0.345 (Vertical density, dead vegetation, 0-10 cm) – 4.57 (Vertical density, dead vegetation, 10-20 cm) + 3.32 (% grass)	= -4 +2 (% bare ground) – 11.52 (% Selaginella) + 4.95 (% grass)
Wald statistic for model	11.65	12.91
Df	3	3
P-value	0.009	0.0049
% overall correct classification (n= 66)	72.1	71.9
Kappa $\pm 2S_K$	0.64±0.14	0.71±0.13

Table 3.8 Habitat variables used in the logistic regression model for the post-hatch 2000 period (significant at p<0.05)

Variable	Wald Chi-square	P- value
Percentage areal cover of grass	6.72	0.010
Percentage areal cover of bare ground	3.86	0.049
Percentage areal cover of Selaginella	4.63	0.031

Table 3.9 Wetland variables significant (p<0.05) in multiple regression analysis for the 1999 pre-lay period

Variable	Beta value	SE of Beta	b- value	SE of b	p- value
Class I	0.212	0.101	0.493	0.233	0.037
Class VI, cover type 3	0.234	0.104	1.100	0.486	0.026
Total number of wetlands	0.311	0.101	0.439	0.143	0.003

ponds) and class VI, cover type 3 (alkali wetlands), as well as the total number of wetlands (Table 3.9).

The same staging site was used prior to migration in both 1999 and 2000. A large alkali slough near Crane Lake surrounded by grazed native pasture was used in both years.

3.5 Radio telemetry

Although the small sample size of radio-tagged chicks (n= 7) precluded complete statistical analysis, I used ArcView 3.2 to calculate basic descriptive statistics (Table 3.10) and to diagram chick movements and area covered (Appendix A). The mean average distance traveled by the radio-tagged chicks between fixed locations was 5721m. I took location fixes for each chick every two to three days. The mean area between the outlying points of movements (minimum convex polygon (MCP) area) was 135.6 ha.

I used Statistica (version 6.0, StatSoft. Inc, Oklahoma, USA) to perform a t-test to compare movement distances between groups of chicks that were in areas with one available habitat (Group A, n= 3) and those in areas with more than one available habitat type (Group B, n= 4; Table 3.11). Chicks in Group B traveled a mean total distance of 4654m, whereas those in Group A traveled 7143 m (Table 3.11). This must be taken in context with the fact that Group A birds were followed significantly longer (x= 28 days) than B (x= 19 days; t= -4.00, p= 0.01).

Group B birds travelled a mean distance of 2455m (SD= 3461) between fixes, whereas Group A had a mean of 869 m (SD= 412; Fig. 3.6) although the difference was not significant (t= 0.77, p= 0.48). The MCP area was larger for Group B (161.3 ha) than for Group A (101.3 ha; Fig. 3.7), although this difference was also not significant (t= 1.15, p= 0.30).

Of the seven radio-tagged chicks, two were killed by predators. The remains of one were found in the native pasture, where the bird had been tracked extensively. The radio-transmitter was located in a pile of feathers. The remains of the other chick included a skull, legs with bands still present, and feathers. This chick had not been located for approximately one week before finding the carcass.

Table 3.10 Descriptive statistics for radio-telemetry data (n= 7)

Variable	Mean±Std.Dev.	Minimum	Maximum
Min. distance (m)	334.0±247.9	151.5	874.0
Max. distance (m)	1339.0±746.6	280.8	2641.0
Total distance (m)	5721.0±2867.9	1577.2	10762.0
Mean distance (m)	1776.0±2601.2	496.5	7641.0
Duration of study (days)	23.0±5.7	14.0	30.0
MCP area (ha)	135.6±67.0	45.9	231.9
# of Habitats used	2.0±0.9	1.0	3.0

Distances = distances traveled by chicks between location fixes, MCP area = area within the minimum convex polygon

Table 3.11 Comparison of radio-telemetry data between chicks in Group A (n= 3) and Group B (n= 4)

Variable	Mean ± Std.Dev. Group B	Mean ± Std.Dev. Group A	t-value	p-value
Sample size	10±1.3	9±2.5	0.12	0.91
Min. distance (m)	232±77.3	470±356.1	-1.34	0.24
Max. distance (m)	1119±673.0	1633±875.8	-0.88	0.42
Total distance (m)	4654±2222.7	7143±3457.5	-1.17	0.29
Mean distance (m)	2455±3461.5	869±412.3	0.77	0.48
Duration of study (days)	19±3.7	28±1.5	-4.00	0.01
MCP area (ha)	161.3±69.4	101.3±66.2	1.15	0.30
# of Habitats	3±0.6	1±0.0	4.39	0.007

Group A= chicks located in areas with one available habitat type, Group B= chicks located in areas with more than one available habitat type, distances = distances traveled by chicks between location fixes, MCP area = area within the minimum convex polygon

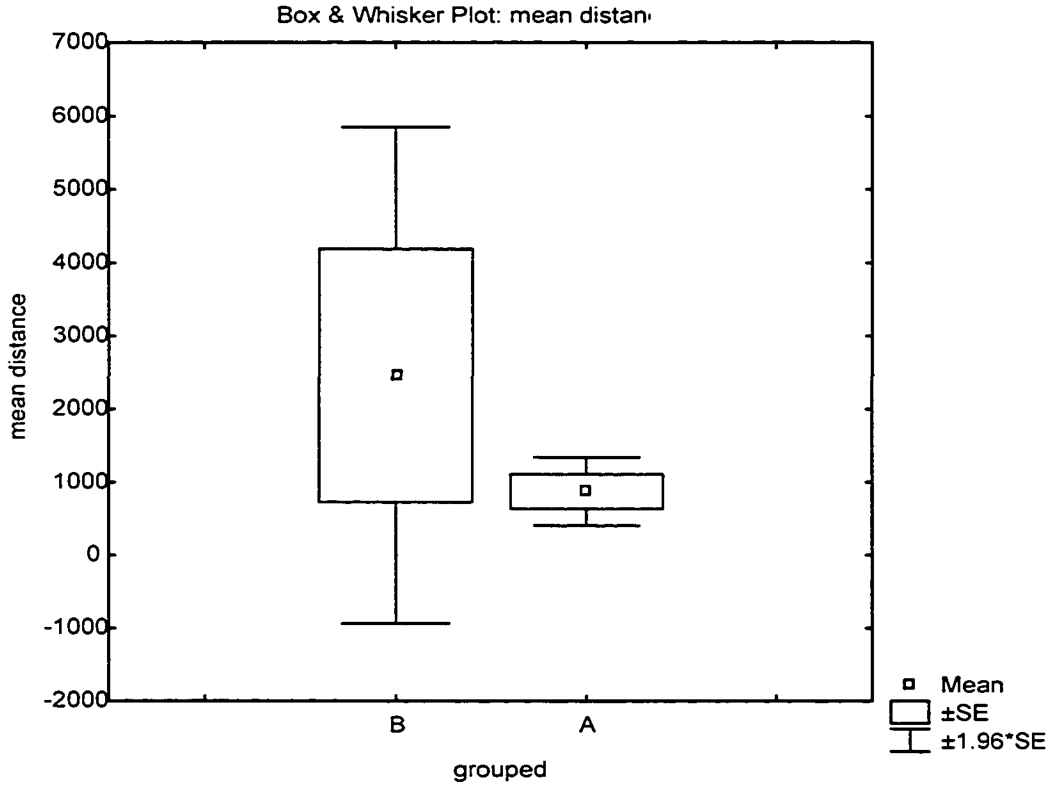


Figure 3.6 Distance traveled (m), variation (±SE), and 95% confidence interval (±1.96*SE) for radio-tagged chicks in Group B (birds in areas with fragmented habitats) and Group A (birds in areas with only one available habitat type)

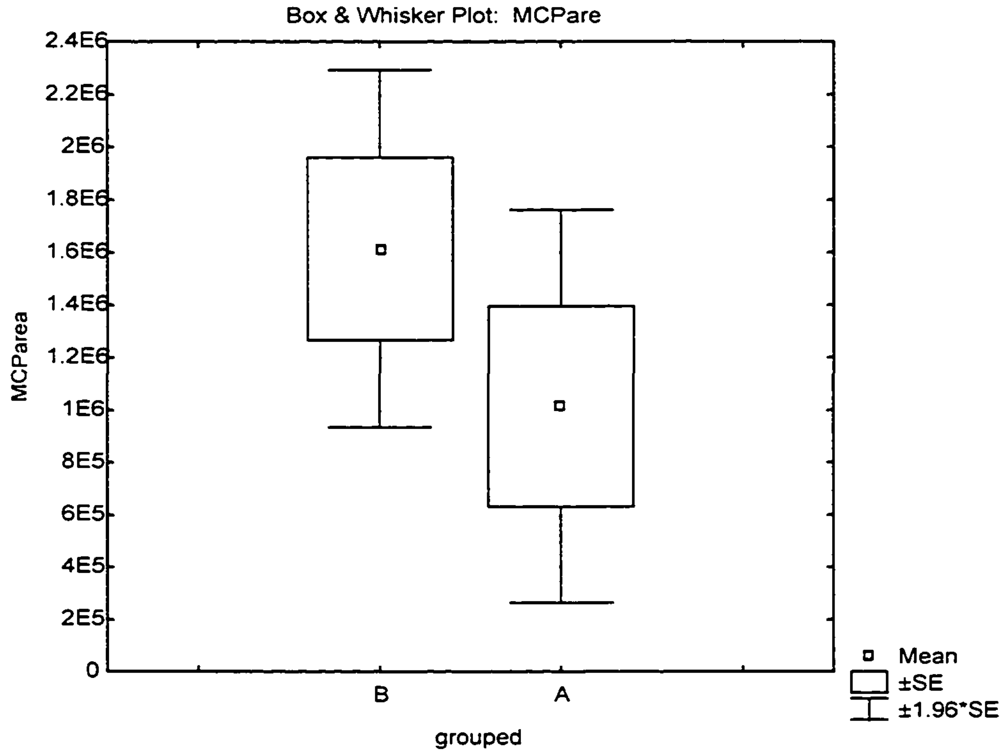


Figure 3.7 The minimum convex polygon (MCP) area (ha) used by chicks in Group B (birds in areas with fragmented habitats) and Group A (birds in areas with one available habitat type)

3.6 GIS and probability surface

Only large-scale spatial data variables were included in the GIS analyses. Variables found to be significant predictors of curlew occurrence at $p<0.05$ were included, as well as variables where $0.05<p<0.10$ if they increased the predictive power of the model.

For each time period, I provide the results of the model that best predicted the incidence of curlews. However, the final probability surface was constructed using a model for pooled data from the pre-lay and post-hatch periods in both years.

The variables used in the models abbreviated as B2, B3, B6H and B7 are Landsat 7 satellite spectral bandwidths. Band 2 (B2) has a spectral range of 0.525 to 0.605 um, Band 3 (B3) is 0.630 to 0.690 um, Band 6 High-gain is 10.40 to 12.50 nm, and Band 7 is 2.09 to 2.35 um. Bands 2 and 3 reflect visible light and have peaks relating to green land cover, whereas Bands 6H and 7 are near the infra-red spectrum and have peaks relating to increased thermal energy (W. Stafford, pers. comm.; www.landsat7.usgs.gov).

Road buffers included in the models are abbreviated RB, and the number accompanying it indicates the size of the buffer (i.e. 300 m buffer). A road buffer of zero means that no area within the 600 m radius of the sampling point was represented by road buffers. Similarly, river buffers are abbreviated RivB. PWet refers to the presence of wetlands within the sampling point area.

3.6.1 Pre-lay 1999

Through logistic regression analyses, the spatial data variables found to be significant predictors of curlew occurrence were B6H, B3, RB0, RB300, and RivB100 (Table 3.12). RB200 was included in the model (p= 0.079) as it enhanced the ability of the model to correctly classify data. Curlew occurrence was best predicted by a positive trend in B6H, a negative trend in B3, and the absence of road buffers in the sampling areas (Table 3.13).

The model correctly predicted 74.8% of curlew absences (n= 111) and 53.3% of occurrences (n= 90). The kappa value was 0.54 with a 95% confidence interval of 0.46 to 0.62 (Titus et al. 1984; Table 3.13). Thus, the ability of the model to classify data correctly was 46 to 62% better than by chance alone.

The incubation data set was used as hold-out data. The model correctly classified 64% of curlew absences (n= 102) and 60% of occurrences (n= 99) for the incubation period data.

Table 3.12 Spatial data variables used in the logistic regression model for the 1999 pre-lay period (significant at $p<0.05$)

Variable	Wald chi-square	P- value
B6H	8.72	0.003
B3	4.89	0.027
RB0	8.78	0.003
RB200	3.09	0.079
RB300	5.01	0.025
RivB100	4.36	0.037

B6H and B3= Landsat channels, RB0= no road buffers represented within sampling area, RB200= road buffer of 200 m represented within sampling area, RB300= road buffer of 300 m represented within sampling area, and RivB100= river buffer of 100m represented within sampling area.

Table 3.13 Variables included in the logistic regression model used to predict curlew occurrence for the 1999 pre-lay period

Fitted Model for logit response	=-13.58 + 0.04(B6H) - 0.04 (B3) + 0.14 (RB0) + 0.86 (RB200) – 0.48 (RB300) – 0.06 (RivB100)
Wald statistic for model	31.47
Df	6
P-value	0.000
% overall correct classification (n= 66)	65.2
Kappa $\pm 2S_k$	0.54 ± 0.08 (0.46 to 0.62)

B6H and B3= Landsat channels, RB0= no road buffers represented within sampling area, RB200= road buffer of 200 m represented within sampling area, RB300= road buffer of 300 m represented within sampling area, and RivB100= river buffer of 100m represented within sampling area.

3.6.2 Post-hatch 1999

Spatial data variables B7, B3, B2, and RB100 were significant predictors of curlew occurrence during the post-hatch period in 1999 (Table 3.14). The variable Pwet was included although its $p > 0.05$ because it increased the percentage of cases correctly classified. Curlew occurrence was best predicted by positive trends in B7 and B2, a negative trend in B3, and the increasing presence of wetlands within sampling areas (Table 3.15).

For this time period, the model correctly classified 94.2% of curlew absences (n= 138), and 28.6% of occurrences (n= 63). The kappa statistic for the model was 0.66 with a 95% confidence interval from 0.58 to 0.74, indicating good classification power (Titus et al. 1984; Table 3.15). Thus, the model classified occurrence 58 to 74% better than by chance alone.

The hold-out data was classified correctly by the model as 63% for absences (n= 102) and 58% for occurrences (n= 99).

3.6.3 Pre-lay 2000

For the pre-lay period in 2000, I found that curlew occurrence was significantly predicted by a positive trend in B7 and B2, a negative trend in B3, and the decreasing presence of 100 m road buffers (RB100) in the sampling area (Tables 3.16 and 3.17).

The model correctly predicted curlew absences 83.2% of the time (n= 119), and curlew occurrence 51.2% of the time (n= 82). The kappa statistic was

0.62 with a 95% confidence interval of 0.54 to 0.70 (Titus et al. 1984; Table 3.17) meaning that the model classifies cases 54 to 70% better than by chance alone.

For the hold-out data, the model classified absences (n= 102) correctly 76% of the time, and occurrences correctly 69% (n= 99) of the time.

3.6.4 Post-hatch 2000

Using logistic regression, I determined that the variables B7, B3, RB0, RB100, and RB300 were significant ($p<0.05$) predictors of curlew occurrence (Table 3.18). A positive trend in B7 and B2, a negative trend in B3, and an increase in 300 m road buffers in the sampling area are the best predictors of curlew occurrence during the post-hatch period in 2000 (Table 3.19).

This model correctly predicted 95.0% of curlew absences (n= 126) and 30.7% of occurrences (n= 75). The kappa statistic was 0.62 with a 95% confidence interval of 0.54 to 0.70, indicating the model classified occurrences 54 to 70% better than chance alone (Titus et al. 1984; Table 3.19).

The model correctly classified 73% of curlew absences (n= 102), and 67% of occurrences (n= 99) when challenged by the hold-out data.

Table 3.14 Spatial data variables used in the logistic regression model for the 1999 post-hatch period (significant at $p<0.05$)

Variable	Wald chi-square	P- value
B7	11.15	0.0008
B3	6.41	0.011
B2	3.88	0.049
RB100	4.31	0.038
PWet	3.19	0.074

B7, B3 and B2= Landsat channels, RB100= road buffer of 100m represented within sampling area, and Pwet= presence of wetlands within sampling area

Table 3.15 Logistic regression model including spatial data variables that best predicted curlew occurrence for the 1999 post-hatch period

Fitted Model for logit response	= -10.97 + 0.15 (B7) – 0.40 (B3) + 0.40 (B2) - 0.02 (RB100) + 0.60 (PWet)
Wald statistic for model	22.77
Df	5
P-value	0.0004
% overall correct classification (n= 66)	73.6
Kappa $\pm 2S_k$	0.66 ± 0.08 (0.58 to 0.74)

B7, B3 and B2= Landsat channels, RB100= road buffer of 100m represented within sampling area, and Pwet= presence of wetlands within sampling area

Table 3.16 Spatial data variables used in the logistic regression model for the 2000 pre-lay period (significant at $p<0.05$)

Variable	Wald Chi-square	P-value
B7	13.37	0.003
B3	10.30	0.0013
B2	7.06	0.0079
RB100	6.95	0.0084

B7, B3 and B2= Landsat channels, RB100= road buffer of 100m represented within sampling area

Table 3.17 Logistic regression model including spatial data variables that best predicted curlew occurrence for the 2000 pre-lay period

Fitted Model for logit response	= -12.26 + 0.16 (B7) – 0.50 (B3) + 0.53 (B2) - 0.03 (RB100)
Wald statistic for model	26.65
Df	4
P-value	0.00
% overall correct classification (n=66)	70.2
Kappa $\pm 2S_k$	0.62 ± 0.08 (0.54 to 0.70)

B7, B3 and B2= Landsat channels, RB100= road buffer of 100m represented within sampling area

Table 3.18 Spatial data variables used in the logistic regression model for the 2000 post-hatch period (significant at $p<0.05$)

Variables	Wald chi-square	P- value
B7	3.87	0.049
B3	4.44	0.035
RB0	5.89	0.015
RB100	5.38	0.020
RB300	5.43	0.020

B7, B3 and B2= Landsat channels, RB0= no road buffer represented within sampling area, RB100= road buffer of 100m represented within sampling area, RB300= road buffer of 300m represented within sampling area

Table 3.19 Logistic regression model including spatial data variables that best predicted curlew occurrence for the 2000 post-hatch period

Fitted Model for logit response	= -17.9 + 0.05 (B7) – 0.06 (B3) + 0.2 (RB0) + 0.2 (RB100) + 0.69 (RB300)
Wald statistic for model	12.96
Df	5
P-value	0.024
% overall correct classification (n= 66)	62.9
Kappa $\pm 2S_k$	0.62 ± 0.08 (0.54 to 0.70)

B7, B3 and B2= Landsat channels, RB0= no road buffer represented within sampling area, RB100= road buffer of 100m represented within sampling area, RB300= road buffer of 300m represented within sampling area

Table 3.20 Logistic regression model used to create the probability surface

Fitted Model for logit response	= -7.556 + 0.115 (B7) – 0.411 (B3) + 0.433 (B2)
Wald statistic for model	14.96
Df	3
P-value	0.0019
% overall correct classification (n=66)	75.1
Kappa $\pm 2S_k$	0.78 ± 0.07 (0.71 to 0.85)

B7, B3 and B2= Landsat channels

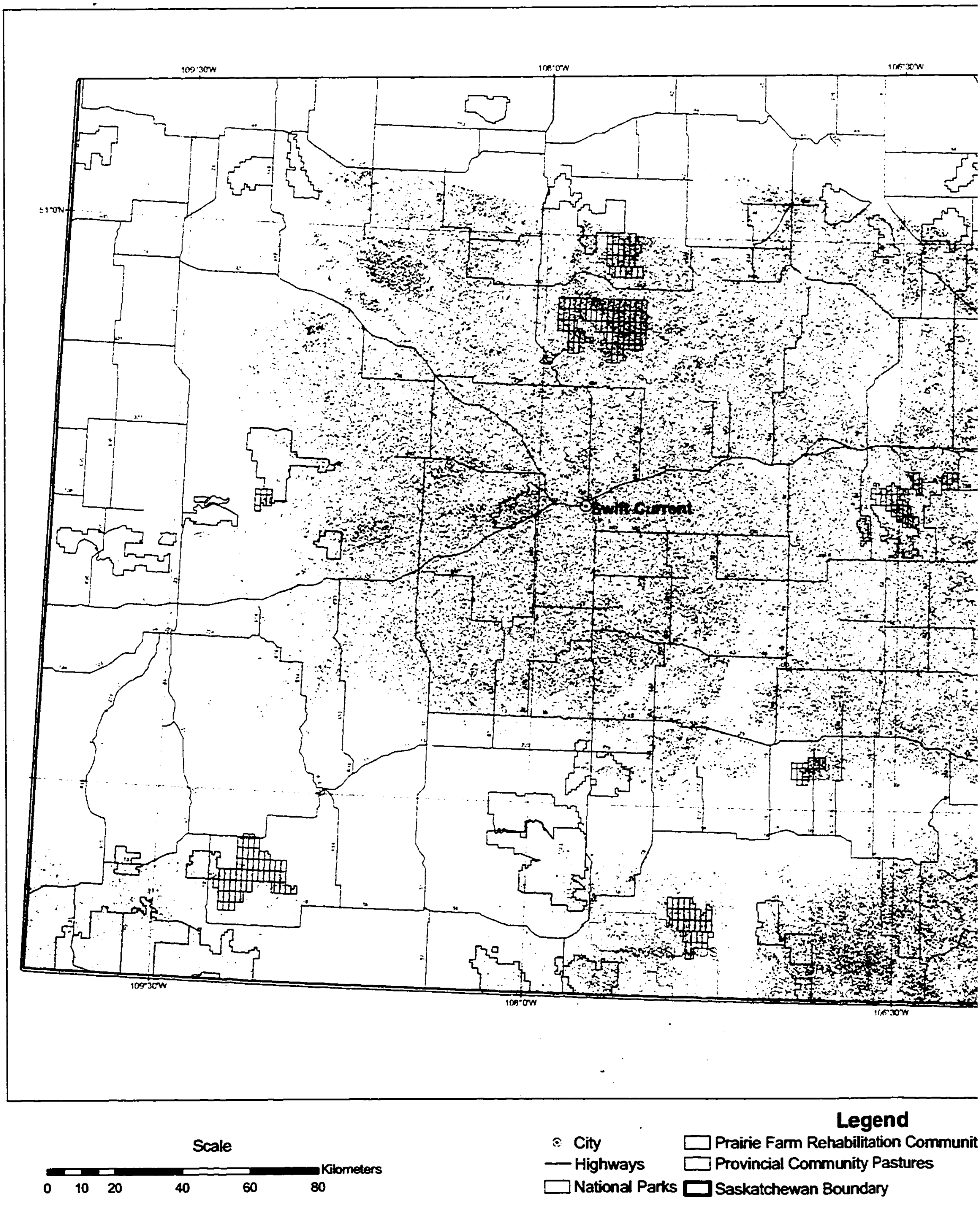
3.6.5 Probability surface

I chose to include the spatial data variables B7, B2, and B3 in the model used to create the probability surface. These three variables were found to be significant predictors of curlew occurrence in most time periods. Typically, curlew presence corresponded with an increasing trend in B7 and B2 and a decreasing trend in B3 (Table 3.20).

I pooled presence and absence data from the 1999 and 2000 pre-lay and post-hatch periods to form one large data set. I then applied logistic regression to generate a model using variables B7, B2, and B3. The model including these variables correctly classified 95% of occurrences (n= 151) and 56% of absences (n= 50). The kappa statistic was 0.78 with a confidence interval of 0.71 to 0.85 (Titus et al. 1984) meaning the model classified occurrences 71 to 85% better than by chance alone (Table 3.20).

The model was entered into Arc-INFO and a surface indicating probability of curlew occurrence in southern Saskatchewan was generated (Fig. 3.8). Although the probability surface did reflect my observations within my study area to some extent, it did not properly identify areas outside the study area as having realistic probabilities of occurrence. Thus, I concluded that this probability surface is not useful for distinguishing areas of probable occurrence in southern Saskatchewan.

Probability of Long-billed C



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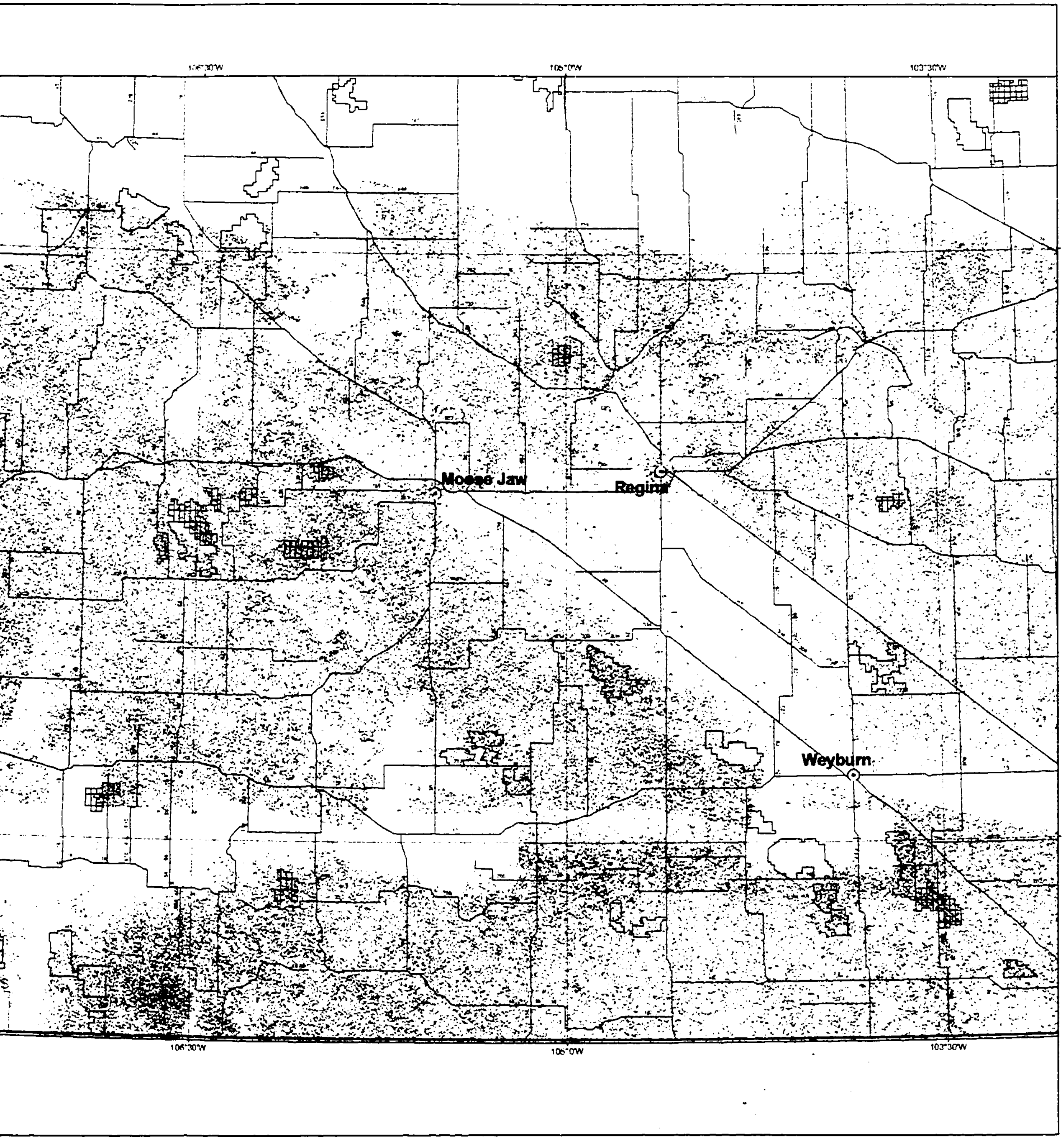

Legend

Prairie Farm Rehabilitation Community Pastures
Provincial Community Pastures
Saskatchewan Boundary

Percent Probability
☐ 0 - 20
☐ 20 - 60
■ 60 - 100

Projection: Universal Transverse Mercator (UTM)
Zone: Extended Zone 13
Datum: North American Datum 1927 (NAD27)
Spheroid: Clarke 1866
Date April 5th, 2003
Janna Foster, Master of Science Candidate

4. DISCUSSION

4.1 Census techniques

Redmond and Jenni (1981) commented that censusing Long-billed Curlews is complicated by aspects of their breeding behaviour and social organization. Their study in Idaho demonstrated that curlews can be accurately counted during the arrival through incubation by a modified Finnish Line transect method. However, such surveys are labour intensive and may require several researchers to cover small areas. Thus, such a method is not likely to be undertaken for large scale, monitoring surveys.

My first objective was to assess large-scale, repeatable census techniques for curlews. I predicted that curlews would readily respond to call playbacks because of their vocal, social nature. Curlews tend to nest close together in loose social aggregates and are known to maintain vocal communication with con-specifics (Allen 1980; Forsythe 1970). In contrast to my predictions, I found that call response playbacks were relatively ineffective at detecting curlews. On average only 49% of known curlews responded to call playbacks.

One reason for this result may simply be that the "wheet-wheet-wheet, curlee-curlee-curluoooo" call itself was not effective in eliciting responses from curlews in the field. This series of calls was chosen because it occurs throughout the breeding season and is given by both sexes (Forsythe 1970). It is typically answered by con-specifics and appears to indicate some sort of anxiety or may be used simply to maintain contact (Forsythe 1970). I expected the broadcast of this call to elicit responses from both sexes. It is possible that the call was ineffective because it was too common of a call. However, if a specific alarm call were broadcast, it could bring in neighbours from nearby habitats, skewing the results. It is also possible that the call response surveys were not effective because the vocalizations I used did not sound like actual curlew calls to the birds themselves. Although the broadcast calls sounded genuine to me, curlews may have been able to distinguish them from true calls. The possibility also exists that curlews were unable to hear the broadcast calls either due to their physical structure or to environmental conditions such as wind. Another plausible explanation for the results is that call playbacks may have suppressed normal curlew behaviour.

It is also possible that the call-response surveys were relatively ineffective because curlews are so conspicuous in open areas. Bogner and Baldasarre (2002) used call playbacks to study the inconspicuous Least Bittern (*Ixobrychus exilis*), a secretive marsh bird whose behaviour and use of dense breeding habitat make it difficult to observe. They found call-response surveys to be an effective tool for locating these birds, which in many ways are the opposite of curlews. Curlews are conspicuous and often demand attention by calling and diving. Therefore, call response surveys may be effective for secretive birds, but do not improve upon traditional listening surveys for more obvious species like curlews.

Another potential reason that call response surveys may have detected fewer curlews than the listening method is the duration of observations. The listening method was employed for five minutes, whereas the call-response period was only employed for two minutes. The reason for this discrepancy in duration is two-fold. First, I predicted that curlews would readily respond to call playbacks within two minutes, as they tend to call more frequently than that under natural conditions. Second, in order to fit all 200 sampling points into a tight time schedule, I could not afford to spend more than seven minutes at each sampling point.

Bogner and Baldasarre (2002) stress that without knowledge about known individuals, it is not possible to determine actual response rates. I believe that my methodology of sampling using the five-minute listening method before employing call playbacks adequately addresses this concern. The listening period provided me with a large sample of known birds to which I could compare responses to the call playback.

Although found to be relatively ineffective, the playbacks did locate additional birds that were undetected in the five-minute listening period. A person wishing to locate curlews in the field could incorporate the use of call playbacks into the survey protocol, but should not rely solely on responses to detect the majority of birds. I recommend using a five-minute listening period as the main survey technique.

I found roadside surveys to work efficiently for my purposes. It allowed me to detect large numbers of curlews and maximized the number of sampling points I was able to survey. There is potential for a bias in the number of birds found depending on a preference for using habitat either near or far from roads.

Other curlew surveys have been successfully conducted from roadsides, suggesting that the benefits of these surveys for this species outweigh such concerns (Cochran and Anderson 1987).

The topography at sampling points was generally flat to gently rolling. Therefore I could easily detect curlews at a radius of 600 m. In areas with more topography, I would recommend using sampling points with a smaller radius. It is possible that taking point counts along walked transects would work better in such areas (Redmond et al. 1981).

There may be a sex bias in curlew observations over the breeding season. Other researchers have found that during incubation, females are less detectable than males and cannot be accurately censused until post-hatch (Redmond et al.1981; Allen 1980). There is little difference in calculated densities for males from arrival through incubation (Redmond et al. 1981). I was not able to assess the existence of such a sampling bias in my study since it was not always possible to sex the birds I detected.

Redmond et al. (1981) suggested that survey sequences should begin at the peak of curlew arrival and end within two weeks, as did my pre-lay surveys. I recommend conducting surveys in late April in Saskatchewan. Curlew numbers in my study were lower post-hatch, although not significantly, than earlier in the season. This decrease in numbers could be due to unsuccessful breeders leaving the breeding grounds (Grant et al. 2000). Incubation studies are not recommended because of the potential sex bias and unreliability resulting from cryptic incubating parents making them harder to detect (Allen 1980; Redmond et al. 1981).

4.2 Seasonal habitat use

Habitats need to meet the requirements of individuals, including providing sufficient prey resources, suitable nest-sites, and protection from predators (Valkama et al. 1998). Thus, a general principle of habitat selection is that birds should select environments in which their survival and reproductive success are highest (Espie et al. 1996). My second objective was to determine the relative importance of native grassland, tame grassland, and cropland ecosystems to curlews in southwestern Saskatchewan throughout the breeding season.

While other studies have investigated habitat selection specifically for nesting or foraging, I simply recorded presence in habitats at various times of the breeding season. I can infer some degree of use from observations and timing, but cannot draw definitive conclusions. For instance, Berg (1992) found that European curlew nests were close to fields where non-incubating parents were foraging, which allowed the non-incubating parent to participate in defense of the nest against predators if necessary. If the same logic is extrapolated to my study, it may be valid to assume that habitat used in pre-lay are either nesting areas or close to nesting areas. I did not make any measures of actual breeding success. Therefore, it is not possible for me to conclude that curlews using various habitats were differentially successful. I can only assume that birds are likely to preferentially use habitats that maximize survival and reproductive success (Espie et al. 1996).

Curlews consistently avoided areas of fallow, stubble, and tame hay throughout both breeding seasons of my study. This is likely due to the lack of cover from predators. Fallow and stubble are very open and may make it easier for predators to detect curlews. Also, curlews nesting on fallow or in fields being prepared for planting would be vulnerable to plowing (Shackford 1994). Other studies have shown that curlews rarely nest in hayland, fallow or stubble fields, but will forage in all habitat types during the breeding season (Cochran and Anderson 1987; McCallum et al. 1977; Allen 1980; Pampush and Anthony 1993). Accordingly, I assert that most birds I witnessed in areas of fallow, stubble and tame hay were foraging rather than nesting.

Generally, tame pasture was used in relation to its relative abundance. Tame grasslands in southwestern Saskatchewan are predominantly crested wheatgrass (*Agropyron cristatum*) monocultures. My observations indicate that curlews were more likely to be found in tame pastures that had been grazed prior to nesting. Bicak et al. (1982) reported that crested wheatgrass pastures were of no benefit to curlews in Idaho, and suggested the conversion of these areas to native short grasses would improve habitat for curlews and other wildlife. However, as millions of acres of crested wheatgrass have been planted across the prairies over the last 10 – 15 years, this increase in pastureland may be important to the species. Curlews do not use extensively cultivated areas, but it is possible that birds may re-occupy these areas after their conversion to expanses of tame pasture. Therefore, the use of tame pasture in relation to its relative abundance may be more important for the curlew population than previously thought.

Areas of spring/summer crop were used more than expected during the post-hatch periods. This represents a definite habitat shift at the time of brood rearing. This is likely due to the increased number of prey items, presumably grasshoppers and/or carabid beetles, in cropland in mid-summer (R. Hooper, pers. comm.). Terrestrial insects are the primary prey for curlews on breeding grounds (Goater and Bush 1986; Redmond et al. 1982). In Idaho, the most frequent and intense use of agricultural land was for feeding before migration (Bicak et al. 1982).

Although curlews used areas of spring/summer crop more than expected, they were generally absent from extensively cultivated areas. The spring/summer crop areas being used were typically in close proximity to pastureland. This is supported by Shackford's (1994) observations that curlews in cultivated fields in Oklahoma tended to choose territories where some grassland was present nearby. Renaud (1980) also suggested that some records of breeding in cultivated land in Saskatchewan might actually represent birds that nested in grassland and shifted habitats while tending broods, and that the species does not use areas with complete cultivation. Although my results demonstrate that areas of spring/summer crop support curlews in post-hatch periods, an increase in these areas causing a decrease in breeding habitat would likely be detrimental.

Between year differences in habitat selection may occur as a result of both internal and external cues and failure to take account of annual variation could result in misleading inferences about habitat selection (Fielding and Bell 1997). Major differences in habitat use in my study area between years include native prairie not being used significantly more than expected in 2000; the use of fall/winter crop more than expected during pre-lay 1999; and the use of tame pasture less than expected in post-hatch 1999.

In 1999, a preference for native grassland was seen throughout the breeding season. This was expected since curlews evolved with native habitats. Many other studies of habitat selection suggest a preference for short or mixed-grass native grassland communities, especially for nesting (Bicak et al. 1982; Cochran and Anderson 1987; Pampush and Anthony 1993; Allen 1980). Surprisingly, in 2000 curlews used native grasslands in the same proportion as expected based on its availability. This discrepancy in habitat use may be due to some different environmental conditions present in 1999 versus 2000. The spring of 1999 was wet and mild. In 2000, spring was relatively late and there was a large snowstorm in early May. This storm was severe enough to cause nest losses for early breeders (W. Harris, pers. comm.). Therefore, it is possible that some birds did not breed due to stress, and early nests could have been destroyed. Because curlews are not known to re-nest, I may actually have observed some curlews using various habitats for foraging, rather than as nesting areas. This coupled with the delay of my surveys due to the inclement weather may explain why no preference for native grassland was detected in

2000. The shift to cropland still occurred post-hatch presumably because curlews tend to move to areas of spring/summer crop for feeding whether they have broods or not (Pampush and Anthony 1993).

Areas of fall/winter crop (primarily winter wheat and fall rye) were used more than expected only in the pre-lay period 1999. Fall and winter crops tend to mimic grassland early in the season. When curlews return and select territories, these areas are green and approximately the same height as native grass. Birds nesting in areas of fall and winter crops would likely stand a reasonable chance of success because these areas are seldom disturbed in spring (Shackford 1994). These areas are usually not disturbed until later in the year. Although fall/winter crop mimics grassland early in the season, the crop grows much faster and taller than grass and may actually be problematic for brood movement and protection. Pampush and Anthony (1993) found that curlews foraged in fields only if the vegetation was less than 30 cm tall. There was more fall/winter crop present in the spring of 1999 than in 2000, which may account for the different result.

Another difference between the two years was that significantly less tame pasture than expected was used during the post-hatch period in 1999. During all other periods, tame pasture was used as expected. This difference is likely a result of the excessive precipitation received in the spring of 1999. The vegetation was lush and tall by mid-summer. Normally tussocks of crested wheatgrass tend to grow taller than native species, but this difference was magnified in 1999. The unusually thick vegetation in tame pastures could have impeded chick movement as well as the parent's ability to detect predators from the ground (Allen 1980; Redmond and Jenni 1986). In Idaho, during a year of abundant precipitation, curlews flew long distances to forage in areas with less dense vegetation (Redmond and Jenni 1986). It is therefore possible that, in mid-summer 1999, curlews avoided tame pastures and foraged in areas with less dense vegetation.

Overall, my results indicate that annual differences in habitat selection may be the result of different environmental conditions. Redmond (1986) found that in a wet year, female curlews flying long distances to forage experienced significant annual differences in reproductive effort. He attributed such variation to changes in environmental conditions. Thus, I believe it is a reasonable conclusion that many of the annual differences witnessed in this study could be due to the abundant precipitation in 1999 in contrast to the snowstorm in May 2000.

In both years, curlews appeared to be non-randomly dispersed across the landscape. Rather they tended to occur in loose social aggregations. The Bitter and Crane Lake areas had markedly higher densities. Other areas within the study, such as the Burstall and Great Sand Hill areas, also contained pockets of birds. Allen (1980) concluded that the presence of curlews in an area attracts con-specifics to the site and increases the probability of obtaining a mate, as well as increasing survival. European curlews tended to defend territories in patches that were less isolated (Berg 1992). I was unable to isolate the confounding effects of the presence of con-specifics in nearby habitats on my habitat investigations. However, I am confident that habitat use trends presented here are representative because markedly higher numbers tended to occur in areas with large tracts of grassland.

4.3 Logistic regression analyses

The influence of various habitat variables, wetland class and number, as well as various spatial data variables on bird occurrence were analyzed using logistic regression analyses. Logistic regression is used to model the relationship between a binary variable and one or more predictor variables, which may be either discrete or continuous (Pampel 2000; Jongman *et al.* 1995). I was specifically interested in finding a combination of predictor variables to explain curlew presence or absence at sampling points.

Logistic regression was chosen over linear regression because my abundance data were heavily weighted with zeroes and violated assumptions of linear regression, namely normality and constant variance (Madden et al. 2000; Pampel 2000; Jongman et al. 1995). Current trends in ecological modeling are moving away from models using linear relationships because of difficulties satisfying these assumptions, while methods such as logistic regression and artificial neural networks are being used more commonly (Manel et al. 1999b).

Although discriminant function analysis is a common means of analysis, it is becoming more common to use logistic regression because this approach requires fewer assumptions, is more robust, and is easier to understand than discriminant function analyses (Manel et al. 1999b). I opted for logistic regression over discriminant function analyses because other studies have shown that logistic regression better identifies true absence and presence and is less sensitive to departures from normality in predictor variables (Manel et al. 1999a; Pampel 2000; Jongman et al. 1995). Also, logistic regression can associate both continuous and categorical variables with binary response outcomes (Kleinbaum 1994).

I fitted logistic regression models using the maximum likelihood method. Maximum likelihood estimation generates estimates of model parameters that are most likely to give rise to the pattern of observations in the sample data set (Pampel 2000). I used a forward stepwise approach to select the variables in the final model. Variables were included in the models if they were significant or provided value in improving predictions (Fielding and Bell 1997). The final models were those best able to correctly classify curlew occurrences and absences. Although many researchers use the proportion of correctly classified cases to assess the effectiveness of their models, others have suggested that further tests are necessary (Titus et al. 1984; Fielding and Bell 1997; Manel et al. 2001).

Cohen's kappa statistic provides an appropriate, standardized and effective statistic for evaluating presence and absence models (Manel et al. 2001). Kappa is the proportion of specific agreement and measures the improvement of the models predictions relative to chance. It is one measure that can be used to assess the effectiveness of the classifying model (Fielding and Bell 1997). A kappa value of zero means there is no improvement in classification relative to chance, and a kappa of one indicates perfect agreement. Kappa is especially useful to ecologists because it removes the effects of chance (Titus et al. 1984). Therefore, in order to better assess the performance of the logistic regression models, I calculated the kappa statistic for each.

In order to test the predictive power of the logistic regression models, I used data collected during the incubation period as a hold-out data set. Various methods of data partitioning are popular for testing predictive models (Manel et al. 2001; Fielding and Bell 1997). However, most researchers do not have a large enough data set to hold back to test the model aside from those used to generate the model itself. In my study, data partitioning was not necessary. The incubation data may have been slightly unrepresentative of the actual number of curlews present due to the difficulty detecting incubating females during this period of time. However, I believe that it was suitable to use these data for these purposes because it simply allows a comparison to be made between where curlews were seen and where they were predicted to occur.

4.4 Habitat variables

Other researchers have found that although measures of location might reveal where a species is found, detailed smaller scale measures more effectively predict occurrence (Manel et al. 1999b). In order to investigate small-scale effects on the incidence of curlews in Saskatchewan, I collected data for a number of habitat variables. Although range science and species-specific vegetation studies are currently popular, due to limitations in time and manpower, intensive range assessments were not possible in my study (Abouguendia 1990).

Logistic regression analyses of habitat variables indicated that curlew presence during the pre-lay period 2000 could best be predicted by increasing vertical density of dead vegetation from 0-10 cm high, decreasing vertical density of dead vegetation from 10-20 cm high, and increasing percentage of grass cover. This model correctly classified an average of 72.1% cases and the kappa statistic was calculated to be 0.64. Both of these measures indicate that this model was effective at classifying curlew incidence. A model is generally considered to be effective if it classifies at least 60% of cases correctly (Odom et al. 2001).

My results indicate that curlew occurrence within the sampling points in the pre-lay period was related to short vegetation height. This corresponds with results of several other studies. Pampush and Anthony (1993) found that in Oregon there was an overall preference for habitats of low vertical profile and low vertical density. Allen (1980) determined that in Washington, curlews preferred to nest in areas with mean vegetation heights less than 20 cm. Redmond et al. (1982; 1986) demonstrated that in Idaho, preferred areas for nesting and foraging had vegetation heights less than 10 cm.

Bicak et al. (1982) postulated several possible reasons for the preference of short, low profile vegetation. First, short vegetation increases the probability of efficient intraspecific communication. Second, curlews may have structural adaptations for predator avoidance under such circumstances. Their long bills and necks allow curlews to forage in areas of short vegetation while simultaneously watching for predators. Third, due to their morphology, tall vegetation may hinder foraging and locomotion. Fourth, feeding preferences may generate habitat selection to some extent. Vegetative structure and food are closely linked because the vegetative structure either is the food, or it is the food base for the birds' prey (Bicak et al. 1982).

My logistic regression analyses also identified increasing grass cover as a significant predictor of curlew occurrence during the pre-lay period. This suggests that areas with more grass present were preferred, corresponding with my earlier findings that grassland areas were used more than or as expected, while cropland areas were avoided at this time. This is also supported by other studies. Allen (1980) reported a preference for nesting in areas with substantial coverage of live and dead grass species (24 and 69%, respectively). Cochran and Anderson (1987) found nests in areas with lower mean percent grass than unused areas. However, within habitats containing nests, nest-sites had higher percent grass cover than random sites.

For the post-hatch period in 2000, the logistic regression model that best predicted curlew occurrence included the estimated percentage cover of grass, bare ground and *Selaginella*. The vertical density of dead vegetation in the 10-20 cm interval tended to be negatively associated with presence, although not significantly. This model correctly classified 71.9% of the cases for this time period. The kappa statistic of 0.71 indicates that this model is better than chance at predicting occurrence.

Again, the estimated percentage cover of grass was a significant predictor of presence. The same reasoning for this result as I discussed above, applies here. Higher percentages of bare ground were significantly related to curlew presence during the post-hatch period. Although this may initially seem to conflict with the finding that birds prefer areas with more grass, it is not necessarily so. This preference for areas with increasing bare ground may actually indicate a patchy distribution of grasses. Some typical native grasses in southwestern Saskatchewan tend to be distributed in irregular or clumpy arrangements (e.g. *Agropyron* spp.). This pattern of grass and bare ground may aid in camouflage for the chicks during the post-hatch period. Chicks are cryptic such that they are very difficult to locate in areas with bare soil and patchy vegetation. On several occasions, I saw chicks clearly and fixed their location well, but as I approached they froze in position in or next to a clump of grass. They were so well camouflaged that I was then usually unable to locate them again.

The estimated percentage coverage of the moss *Selaginella densa* was measured to provide some measure of pasture condition (S. K. Davis, pers. comm.). *Selaginella* binds soil and tends to gain prominence in dry areas and heavily grazed areas (Abouguendia 1990). Thus, the abundance of *Selaginella* may be used as an index of pasture condition. Generally speaking, more *Selaginella* means poorer condition (S. K. Davis, pers. comm.). During the post-hatch period, curlews used habitats that had less *Selaginella*. This could indicate that they select pastures that are in better condition, but could also reflect the fact that at this time birds were often found in areas of spring/summer crop that would have little to no *Selaginella* present.

Curlews' prefer areas with short vegetation, more grass coverage, and little *Selaginella*. This is compatible with moderate grazing regimes. It is possible that for certain habitats, grazing mimics historical ecological disturbances and ones which native vegetation and animals may even depend on. My results support the hypothesis that today curlews may depend on grazing to create preferred vegetation characteristics.

Bicak et al. (1982) investigated the effects of various grazing regimes on curlew distribution and abundance and concluded that numbers were significantly correlated with spring and fall grazing. They also found that numbers were significantly negatively related to vegetation height and vertical density. They recommended that grazing should occur prior to nesting so that there is the least amount of direct influence on the birds. Any grazing regime that reduces vegetation height and density at the beginning of the nesting cycle should be beneficial (Bicak et al. 1982). Cochran and Anderson (1987) found that grazing during incubation was correlated with nest failures in Wyoming. Therefore, the timing of grazing is an important consideration for the management of this species.

4.5 Wetland use

My third objective was to evaluate the relationship between curlew incidence and the proximity of wetlands on the breeding grounds in the summer of 2000. In 1999, my impression was that there was a relationship between curlew abundance and the presence of wetlands within the sampling points.

Nearly half of all birds observed were found at sampling points adjacent to wetlands, but only 27% of sampling points were adjacent to wetlands. Similarly, Berg (1992) found that 63.8% of occupied European curlew territories in Sweden contained water bodies, whereas only 29.8% of non-territories contained water bodies. The presence of water was a significant predictor of presence based on logistic regression analyses. Proximity to water was also considered to be a factor in habitat selection by McCallum et al. (1977) who reported that 68% of Long-billed Curlews in Baca County, CO, were within 400 m of standing water.

In order to classify wetlands proximate to sampling points, I used Stewart and Kantrud's (1971) system of classification for natural ponds and lakes in the glaciated prairie region. This system has many benefits. It is clear and concise, and does not require expertise about wetland vegetation. It provides a realistic means of determining the average class of a wetland in this region (www.greatplains.org).

Surprisingly, logistic regression analyses using both years of data did not reveal any significant relationships between curlew occurrence and the presence of any wetland classes or the total number of wetlands. There was a trend between occurrence and the total number of wetlands for the 2000 pre-lay period, as well as with the presence of alkali wetlands for the 2000 post-hatch period. One possible explanation for the lack of significance was that only wetlands within 600 m radius of the sampling points were included in the analyses. If a critical distance of greater than 600 m existed, my analyses would not have detected the relationship. Another potential reason for these results is the inherent assumption in such analyses that habitats are saturated (Fielding and Bell 1997). Predictive models based on biotic data usually assume habitats are saturated, and when they are not, problems with the models may arise. It is unknown whether it is a reasonable assumption that habitat in southwestern Saskatchewan was saturated.

I performed multiple regression analyses to assess the importance of wetlands using abundance data only for areas with curlews present. Significant results were only detected for the 1999 pre-lay period. Curlew abundance was significantly positively correlated with the presence of ephemeral wetlands (Class I) and alkali wetlands (Class IV, cover type 3), as well as the total number of wetlands. These results were expected for all time periods as I often observed curlews in areas close to water. Perhaps a relationship could not be detected in the other time periods for the reasons mentioned above. It is also possible that this may have been due to the large amount of precipitation during the spring of 1999 and the existence of several large ephemeral ponds that year causing curlews to be recorded more often in wet areas during this period. On several occasions in 1999, I observed curlews bathing themselves in ephemeral ponds.

Curlews were seen staging in the same location near Crane Lake, SK, in late July of 1999 and 2000. The staging area was a large, shallow alkali slough that was mostly dry by the end of July. The slough was surrounded by continuously grazed native pasture that was often used by staging birds in the heat of the day. Curlews were seen probing the slough for prey, sitting on the slough hiding their bills, and flying back and forth into the adjacent pastureland. There are reports that this area was also used as a staging site in 2001 (L. Strauss, pers. comm.). Curlews had been seen staging at a nearby slough in a previous year, but that slough was completely dry. This indicates that curlews are loyal to staging areas as long as water is available.

4.6 Radio-telemetry

Chicks presumably have requirements distinct from those of adults. These include the need for an accessible, abundant invertebrate prey base, ample protection from predators, and vegetative structure providing shade, but which allow unimpeded locomotion. I undertook a radio-telemetry study in 2000 to quantify the habitat and wetland use by chicks. Telemetry was necessary for this because chicks are extremely well camouflaged and their movements cannot be directly observed. In 1999, I rarely observed young curlews after 1 July. In fact, radio-transmitter signals were often the only indication of the presence of chicks in July 2000.

I used a necklace style transmitter attachment for several reasons. I considered implanting the transmitter following Mauser and Jarvis (1991), but was not comfortable performing the procedure having not had any surgical experience. Backpack style attachments have been used for adult birds in several studies (e.g. Sutter et al. 1996). However this method is not recommended for chicks whose feathers are not as strong and well developed (Paton et al. 1991; Hooge 1991). Gluing radio transmitters to the chicks was not an option because the chicks would molt and shed the transmitter (Mauser and Jarvis 1991). Using sutures is not believed to be very effective for chicks as they may pull out as the bird grows (Mauser and Jarvis 1991). The necklace style attachment has been used for other birds with similar life histories (Peter Sanzenbacher, pers. comm.) and resulted in fewer negative impacts on the birds.

The elastic necklace allowed flexibility as the chicks grew and moved about. I chose units that were adjustable to allow for the appropriate tightness for each individual. The necklace was fitted at the base of the curlew's neck. Due to the length of the bill and the body shape, chicks were not able to get their bills caught underneath the elastic. I attempted to tie the necklaces such that they hung tightly to the body, yet the chicks would not be constrained by the necklace as they grew.

I assumed that the radio-tagged chicks were behaving normally, however there is some evidence (Hooge 1991; Paton et al. 1991) that subjects carrying radio-transmitters may exhibit different behaviour due to the transmitter itself. Because the transmitters weighed only about 2% of the chicks body mass and were not constricting, I believe the impact of the transmitters on behaviour was minimal.

Chick locations were recorded every two or three days. The movements of the chicks are assumed to be straight-line distances between known fixed locations. The distances traveled by chicks would in reality be much larger because the chicks likely wandered between points during the period between fixes (Redmond and Jenni 1986). The mean total distance traveled for the seven radio-tagged chicks was 5721∀2868 m and the mean MCP area was 135.6∀67 ha. These are larger than data for Idaho, where Redmond and Jenni (1986) found the range of mean total distance for radio-tagged chicks to be 30-2220 m. Chicks are obviously using substantial land areas in Saskatchewan. These results demonstrate the need for management of large areas of habitat.

Although there were no absolute patterns in the movements demonstrated by all seven chicks, some tendencies were clear. Radio-tagged chicks remained in a relatively small area for a period of time before making a longer movement. Chicks often returned to previously used areas. These tendencies have also been recorded in other studies. All radio-tagged broods in Idaho made short and long distance moves (Redmond and Jenni 1986). The chicks would make long distance moves and then remain in that area for a few days. Movements also tended to include a substantial movement returning to previously used areas. Allen (1980) found daily brood movements in Washington to be of two patterns, presumably a function of the habitat available. At one study area with more shrubs, chicks moved from the fields into the south ridge area where at first they were found in different locations each day. Then sometime in the first two weeks, each brood could be found daily in one specific area. At another study site in more open, larger expanses of grassy habitat, broods followed a daily routine of moving toward the river from the nest area in the early morning, feeding in the fields along the bluffs during the day, and then heading back toward their nest area in the late afternoon and evening.

I compared radio-telemetry data between groups of chicks in areas with one available habitat (Group A) with chicks in areas with more than one available habitat type (Group B). Two of the three chicks in Group A were located in areas of vast native grassland. The third was found in a sizeable area of crested wheatgrass habitat. Chicks in Group B were in areas containing a mixture of tame pasture, native pasture, tame hay, or spring/summer crop.

Despite the small sample size, my results indicate the existence of trends in habitat use by curlew chicks. Significant differences between groups were in the number of habitats used and the duration of study as Group A was studied significantly longer than Group B. Due to this difference in duration of study, the total distance traveled by chicks in each group is not a directly comparable measure. The mean distance traveled between location fixes, on the other hand, provides some insight. Group B tended to have a larger mean distance traveled than Group A. Group B chicks exhibited much greater variation in mean distances traveled than those in Group A. The differences were not significant likely due to the small sample size.

Notably, the minimum convex polygon (MCP) area was also larger for chicks in fragmented areas (Group B) than for those in areas of one habitat type (Group A) despite having been studied for less time. Again, although not significant, this implies the possibility that chicks in areas without large expanses of available habitat may move larger distances to find optimal habitat.

The interactions I observed between chick movement and available habitats have been reported in other studies. Redmond and Jenni (1986) concluded that the space a curlew brood requires depends on habitat quality, which varies greatly among and between years and sites. Berg (1992) studied habitat use in the European curlew, similar to the Long-billed Curlew in life history and size. He found that territory size depended to an extent on the spatial distribution of grasslands. Berg (1992) proposed that fragmentation has forced European curlews to establish larger territories in modern farmland than in areas of grassland. My data indicate the same may be true for the area of use by Long-billed Curlews broods.

Chicks in fragmented habitat may be required to move larger distances to find optimal habitat for predator avoidance or foraging (Berg 1992). However, the greatest influence on habitat selection is likely the need for cover to minimize the risk of detection by predators. Chicks are readily taken by a variety of predators (Redmond and Jenni 1986; Allen 1980).

Two radio-tagged chicks were detected in the immediate vicinity of the large alkali slough used as a staging area. I initially captured these chicks within four kilometers of the slough. They moved toward the wetland as brood age increased, and used adjacent habitats until their subsequent death and migration. This suggests that wetlands may be especially important to young curlews prior to migration.

Of the seven radio-tagged chicks, two were killed before the end of study. The diversity of potential predators and stage of carcass decay made it difficult to identify the predator responsible. However, curlews are known to suffer high pre-fledgling mortality and have low annual productivity (Allen 1980; Redmond and

Jenni 1986). In my study, chicks were approximately two weeks of age when radio-tagged and younger birds likely suffer the highest rates of predation (Allen 1980).

4.7 GIS and probability surface

Geographical Information Systems (GIS) is a useful tool for ecologists attempting to map distributions of animals. GIS technology provided the spatial data variables entered into my logistic regression models, and allowed models to be mapped, tested visually for realism and used to predict areas of probable curlew occurrence (Loyn et al. 2001). The ability to use predictive modeling is an important first step for adequate management of poorly understood resources, including rare or endangered species (Odom et al. 2001).

I performed logistic regression analyses with various spatial data layers and my presence/absence data. I discovered that Landsat 7 Thematic Mapper bandwidths two, three and seven were significant predictors of curlew presence over the two seasons of study. There was a direct correlation between objects and their relative reflectances such that various surfaces may be recognized and distinguished. The Landsat bandwidths are representative of areas with lower vegetation and higher thermal energy (W. Stafford, pers. comm.). The logistic regression model containing the variables of bandwidths seven, three, and two was used to generate the probability surface. The model was efficient at predicting presences and absences within my study area. It correctly classified an average of 75% cases for data pooled from the pre-lay and post-hatch periods in both years.

Some road buffer variables were significant predictors of curlew occurrence at sampling points. This indicates that a proportion of the area within the sampling point was represented by roads or set buffer distances surrounding the roads, and this affected curlew presence in the sampling point. For the pre-lay period in 1999 and post-hatch period in 2000, I found that the absence of roads (road buffer= 0) was related to an increase in curlew numbers in an area. During the post-hatch periods in 1999 and 2000, as well as the pre-lay period in 2000, presence was significantly correlated with decreasing road buffers at 100 m. Thus, occurrence was best predicted by the decrease in area represented by road buffers of 100 m at sampling points. In Idaho, curlew density was inversely related to the sophistication of roads present (Redmond and Jenni 1981). I chose to not include road buffer variables in the model used to create the probability surface. The relationships between road buffer variables and bird occurrence may have been a function of my survey methods rather than an actual preference exhibited by curlews.

Using the logistic regression model generated from survey data and Landsat bandwidths two, three, and seven, I created a probability surface that calculates the probability of a curlew occurring in 30 m units across southern Saskatchewan. The surface indicates that curlews are not distributed evenly across habitats, but select habitats based on a number of cues (Loyn et al. 2001). The probability surface was visually tested for realism and deemed to be somewhat representative of my observations within my study area. I found that curlews were not likely to occur in extensively cultivated areas, areas with trees or many shrubs, nor directly in water bodies. The probability surface correctly identified these as areas with zero to low probability of curlew occurrence, while identifying the areas of markedly higher densities within my study area as having high probability of curlew occurrence. However, the surface also predicts probability of occurrence in areas known to be unused cultivated fields. This discrepancy is likely due to the nature of satellite imagery. Satellites do not distinguish between habitat types, but rather detect reflectances. Therefore, it is possible that various habitats may have similar reflectances. I used imagery for southern Saskatchewan that was captured during June and July 2000, at which time crops were growing. At the time of capture, crop fields would have been similar to native or tame pastures in height, colour, and consequently, reflectance and thermal energy. This similarity may account for the predicted probabilities of occurrence within cultivated areas.

Problems arose when the model was extrapolated to habitat outside the study area. The probability surface indicates high probabilities of curlews throughout southern Saskatchewan, even areas of extensive cultivation such as the Regina Plain. There are a number of factors that may contribute to this inaccuracy. Because much of south-central and southeastern Saskatchewan is cultivated land, the problem regarding the timing of imagery capture mentioned above would certainly apply here.

The inprecision of my probability surface may also be due to a difference in resampling techniques used to correct satellite imagery. Resampling is necessary because satellite imagery is captured in scenes as raw data, which contains various geometric and geographic locational errors from a number of sources. Some sources of error include the rotation of the earth during image acquisition, the curvature of the earth, and panoramic effects relating to the imaging geometry. In order to counter such errors, imagery must be corrected, and resampling is a common means of doing so. Resampling is an interpolation technique in which brightness values for each cell in the output raster data are interpolated from the uncorrected raw satellite image (www.auslig.gov.au). There are various means of resampling Landsat data, including cubic convolution and nearest neighbour techniques. Cubic convolution was the technique used to resample image data for the scene containing my study area. This is an intense interpolation method which determines the value of a new cell by fitting a cubic polynomial surface to a 4 x 4 neighbourhood of cells (www.gisdevelopment.net). Nearest neighbour resampling was applied to the data in the rest of the scenes covering southern Saskatchewan. Nearest neighbour sampling calculates the value of a cell by computing the distance between the center of each cell in the output raster and the four nearest cells in the input raster (www.gisdevelopment.net). I was unable to use a nearest neighbour resampled scene in my area because the only available scene of this type contained areas of cloud cover directly above many of my sampling points. Unfortunately, cubic convolution resampled scenes were not available for the remainder of southern Saskatchewan. This difference in resampling method also challenges the validity of extrapolating my model to habitats beyond my study area.

Another potential reason for the inaccuracy of the surface is the difference in precipitation between southwestern Saskatchewan and the rest of the south during the summer of 2000 when the imagery was captured. The southwest, including my study area, received little moisture during the summer of 2000, whereas the southeast received abundant precipitation. Therefore, areas in the south-central and southeast likely had more lush, green vegetation than my study area. Since my probability surface was generated based on a model created with data from my study area, it may not be valid to extrapolate the model to other areas experiencing different environmental conditions.

Habitat scale may also limit the utility of the probability surface. Since I did not determine actual territories sizes for curlews, the size of units has been set at 30 m pixels due to the nature of the satellite imagery. However, if curlews require larger expanses of territory with the same predicted values this would impact the output (Fielding and Bell 1997). Due to all of the previously mentioned problems, the probability surface generated here is simply not useful.

4.8 Management recommendations

To prevent a species' extinction, we must know where they occur and what their status is (CESCC 2001). My study clarifies the relative importance of native grassland, tame grassland and cropland areas for curlews in Saskatchewan. Although a two-year study cannot detect a population trend, my results provide a basis for future monitoring efforts. Surveys repeated at my sampling points will provide insight into population trends.

Saskatchewan needs a standardized, recurring survey for these birds in order to assess the provincial population trend. Although I detected substantial numbers in my study area, Breeding Bird Survey data does indicate a decline. Hill (1998) also suggested that it would be prudent to carefully monitor curlew populations considering the continental population trend. Monitoring is especially important for curlews because they are generally long-lived and produce few young each year. This makes populations vulnerable to increased adult mortality, and declines are more likely to go unnoticed until well underway (Hill 1998; Redmond and Jenni 1986).

Effective management depends on the implementation of standardized population surveys, and the protection and maintenance of the remaining native grassland habitats (Hill 1998). De Smet (1992) argues that while some might contend most grassland habitat losses occurred in the past and continued loss of habitat is not a concern, several reports indicate that in fact native prairie habitats continue to be destroyed. He asserts that more and more native grasslands will be converted to cropland unless there is a change in agricultural directives and incentives. In my study, curlews were most often observed in native grassland habitats. This preference coupled with potentially large territory sizes is obviously a limitation for the population as expanses of grassland are no longer common. Bicak et al. (1982) claim that the size of the breeding population in their study area was directly limited by the amount of suitable habitat available. Obviously the maintenance of the remaining native grasslands is crucial for the conservation of this species.

A number of permanent cover programs exist in Saskatchewan. In the ten years between 1991 and 2001, approximately 1.43 million acres of cultivated fields were converted to some sort of permanent cover, including tame pasture or tame hay fields (Riemer 2003). The impact of such programs on bird numbers is not well understood. These areas may be of importance to the species, especially considering that curlews used tame pastures in relation to their relative abundance. I assume that any decrease in the amount of cultivated land and increase in permanent cover would be beneficial. Managers should try to seed using native grass species whenever possible (Cannings 1999). If crested wheatgrass has been seeded, it should be maintained by grazing to be most beneficial to curlews.

Although curlews used areas of spring and summer crop more than expected in the post-hatch periods, crop farming is generally detrimental to curlews. This is evidenced by the lack of birds in areas of extensive cultivation. Ranching practices, however, tend to sustain preferred breeding habitat (Hill 1998).

Moderate grazing in the early spring or fall is beneficial. I demonstrated that curlews prefer areas with short vegetation which grazing produces. Grazing during the incubation period should be minimized to reduce the risk of nest loss (Bicak et al. 1981). If grazing is not an option, haying may be used to create short vegetation for curlews. Haying should be done either late in the season to avoid killing chicks or very early to avoid nest loss (Cochran and Anderson 1987). In Saskatchewan, I recommend not haying until mid to late July when chicks can fly to avoid being crushed by farm equipment. Haying prior to nesting would likely cause damage to the fragile vegetation.

Curlew breeding habitat should be protected from detrimental human activities including the construction of new roads, the unlimited use of off-road vehicles, and littering (Redmond and Jenni 1986; Cannings 1999). For instance, many roads and hundreds of new oil/gas wells have been constructed in southwestern Saskatchewan in areas of high curlew density. The effects of such development are not clearly understood, but likely has a negative impact. Redmond and Jenni (1982) demonstrated that females are less likely to return to nesting areas in which they suffered losses or disturbance. They also found that territories are not established within 0.4 km of areas of frequent human use. Obviously, human disturbance has implications for management.

A number of other factors may also impact this species. Cochran and Anderson (1987) found that fertilizing and dragging to break up cow dung reduced nesting productivity. If these activities are necessary, the breeding chronology of the curlew should be considered in decisions about timing. There is some evidence that drought may reduce breeding success (Hill 1998; Allen 1980). Land managers should consider the possibility of drought and the impact it may have on the curlew population. Changes in livestock grazing intensity and wetland use could be made accordingly. The effects of fire suppression should also be considered. Redmond and Jenni (1986) found that during the breeding season following a fall range fire, there was a 30% increase in the breeding curlew density in that area. Fire removes shrubs and thick vegetation, thereby improving habitat for curlews, Burrowing Owls, and Loggerhead Shrikes (*Lanius ludovicianus*; Pampush and Anthony 1993). If a prescribed burn is to take place, burning should not occur during the breeding season.

The curlew spends the majority of its time on the wintering grounds. Therefore, interactions with government agencies in countries where curlews are wintering are also needed for meaningful conservation efforts. We should encourage curbing the destruction of tidal habitats and the use of harmful pesticides.

Long-billed Curlews are an ideal symbol for grassland conservation efforts (Cannings 1999). Public education regarding the curlew, other prairie species, and the plight of the prairie grasslands are essential to conservation efforts. For example, Dinosaur Provincial Park Resource Management Plan in Alberta adopted the use of the curlew as a representative of prairie species for public awareness and education programs within the park (Hill 1998).

The limited distribution of curlews in Saskatchewan and the potential threats to their preferred habitat necessitate conservation efforts. It is up to land managers and government agencies to maintain breeding habitat. As Taverner wrote in 1926, "Whether we can retain such a large and conspicuous bird in settled country remains to be seen; this rests largely with the popular feeling of the communities they inhabit."

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APPENDIX A

A. Radio telemetry data

Table A.1 Summary of data for radio-tagged chicks (n= 7)

Chick Number	57533	57534	57535	57537	57539	57540	57543
Grouping variable	B	B	A	B	A	A	B
Number of habitats used	2	2	1	3	1	1	3
Duration of Study (days)	19	14	27	20	30	28	23
Minimum Distance Traveled (m)	183.11	313.63	874.29	151.51	334.55	202.10	280.80
Maximum Distance Traveled (m)	1806.64	1488.16	2641.06	901.74	1196.14	1061.21	1577.20
Mean Distance Traveled (m)	785.15	898.39	1345.27	496.48	617.51	645.63	764.15
Total Distance Traveled (m)	6281.19	6288.76	10762.18	4468.33	6792.66	3873.77	7641.46
MCP Area (ha)	173.03	231.90	174.57	65.68	83.27	45.93	174.54

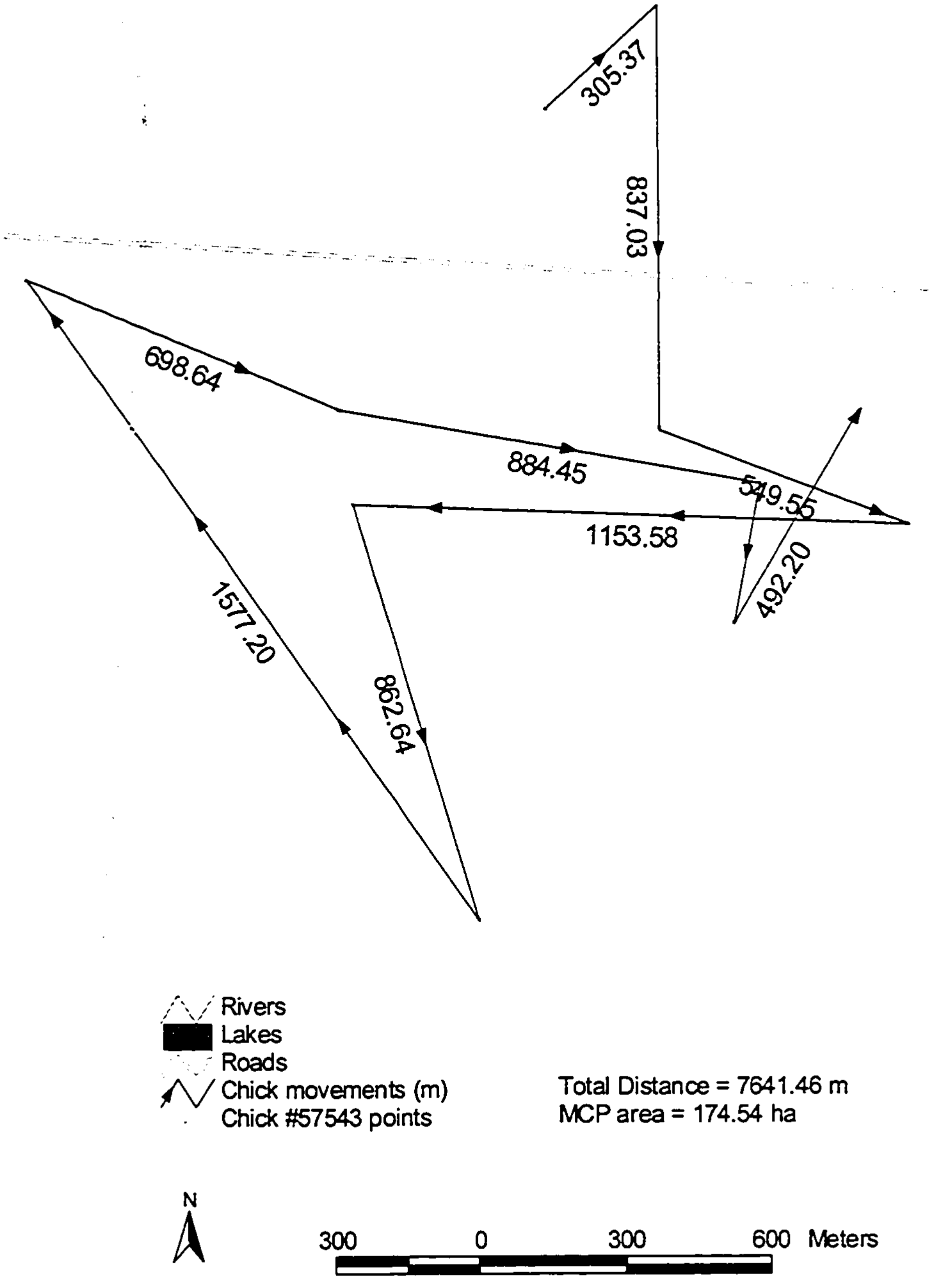


Figure A.1 Movement distances and pattern of radio-tagged chick 57543

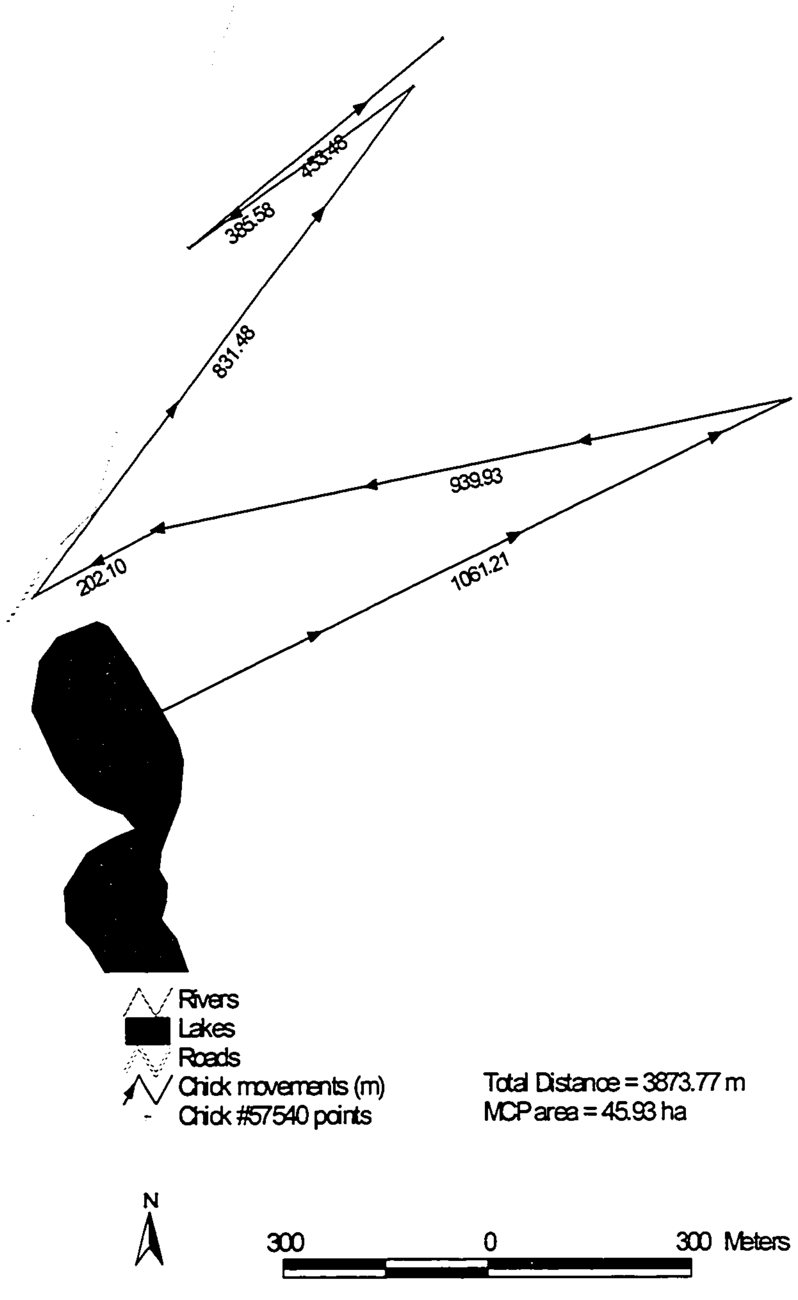
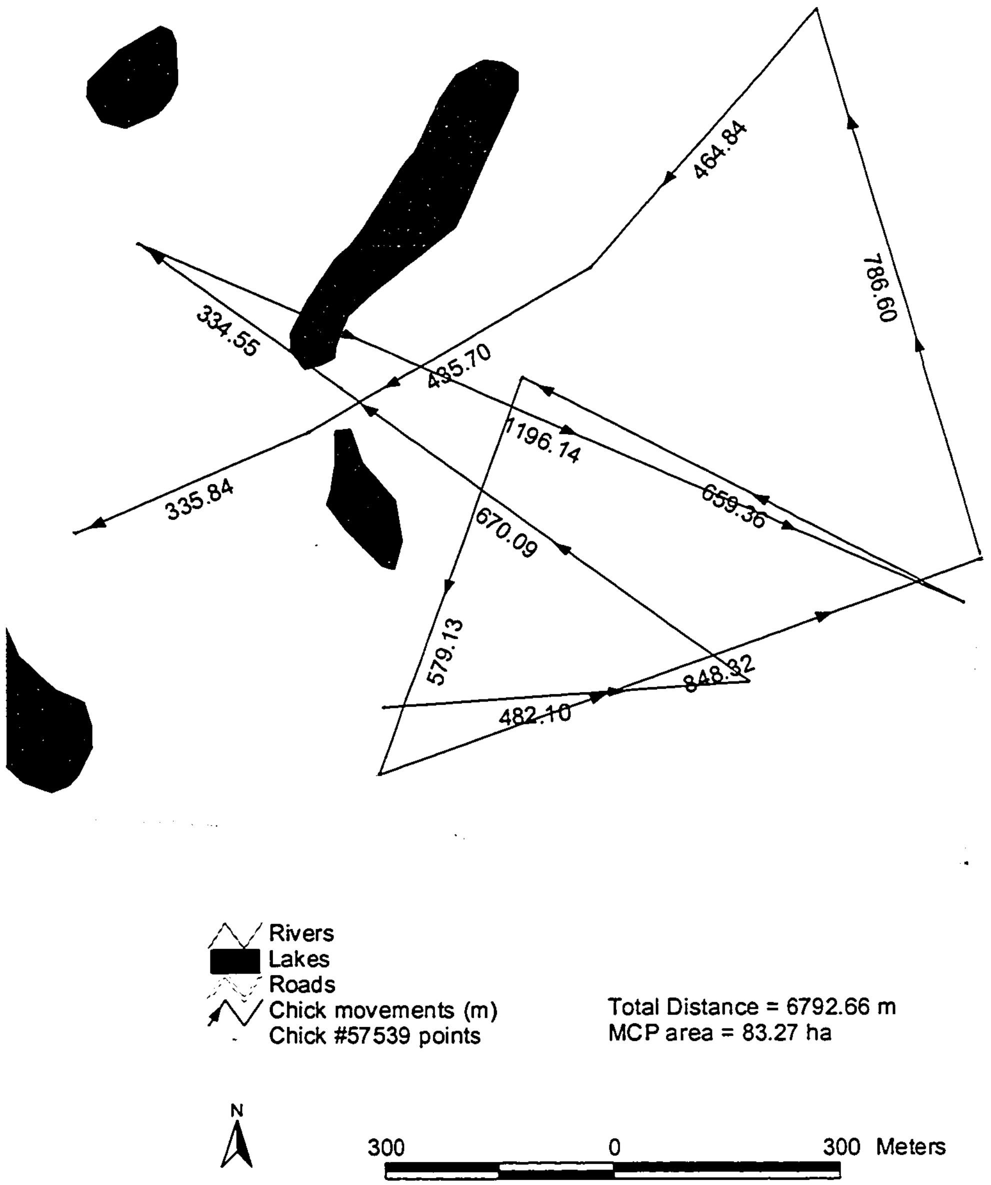


Figure A.2 Movement distances and pattern of radio-tagged chick 57540



Total Distance = 6792.66 m
MCP area = 83.27 ha

Figure A.3 Movement distances and pattern of radio-tagged chick 57539

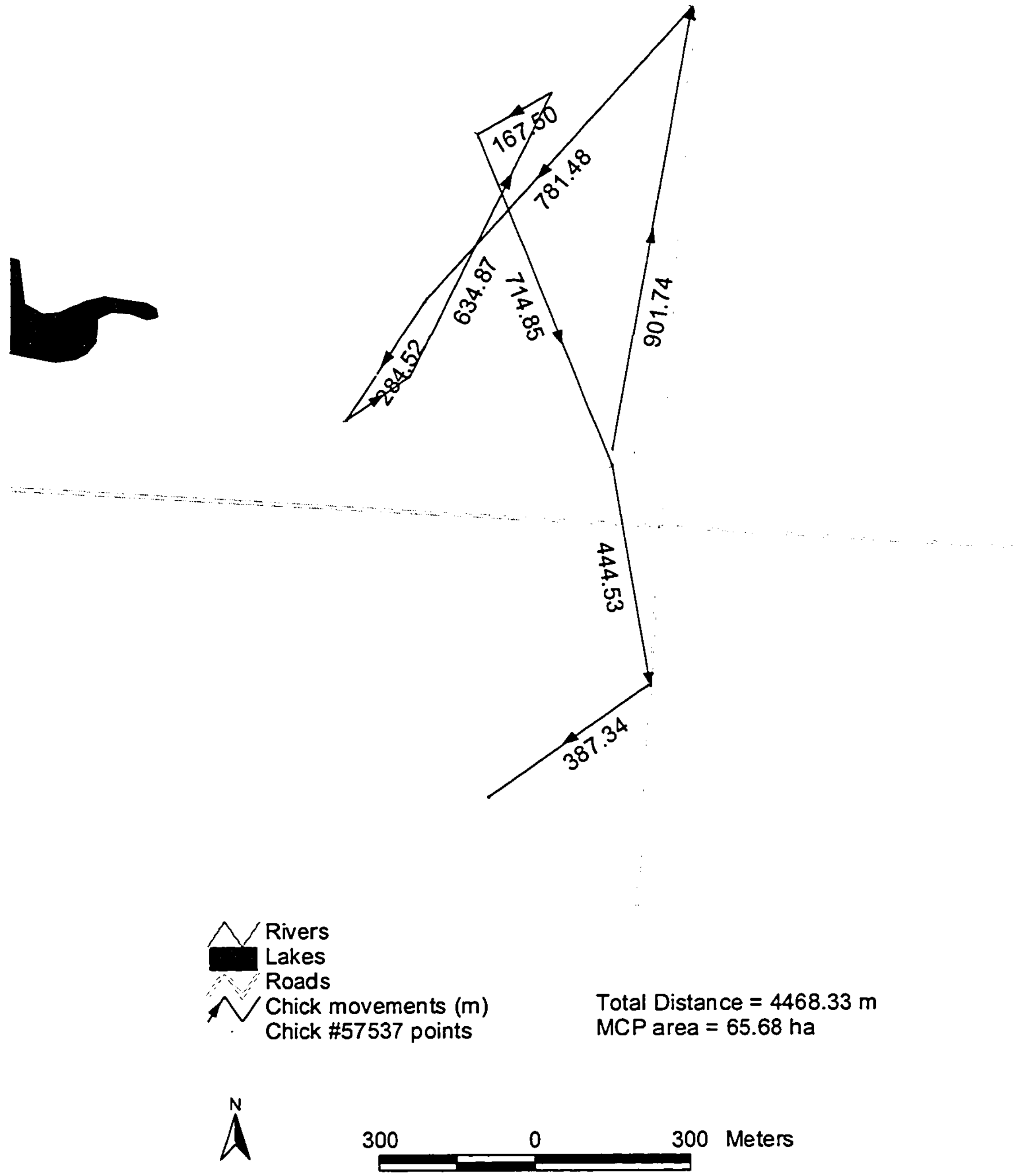
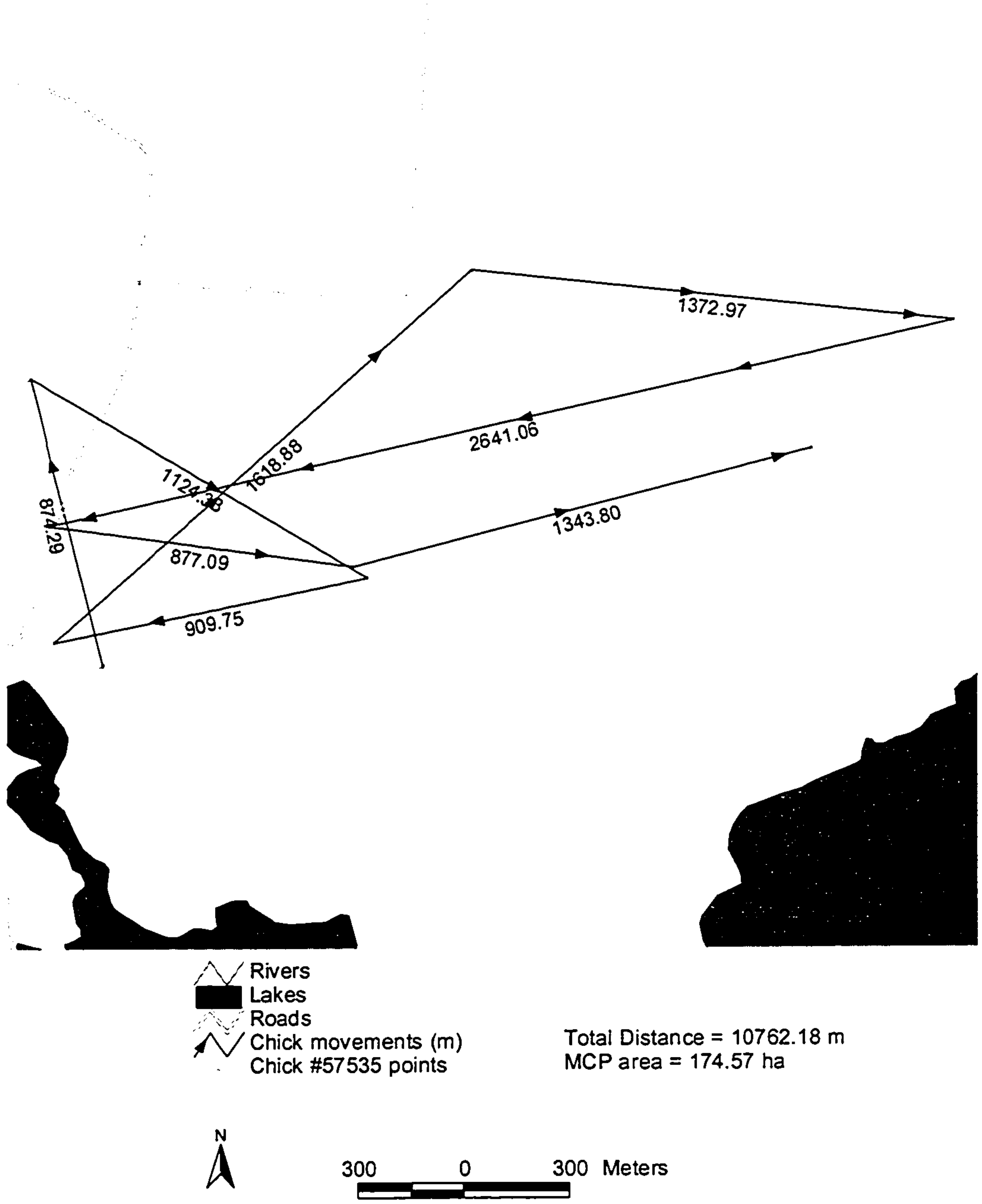


Figure A.4 Movement distances and pattern of radio-tagged chick 57537



Total Distance = 10762.18 m
MCP area = 174.57 ha

Figure A.5 Movement distances and pattern of radio-tagged chick 57535

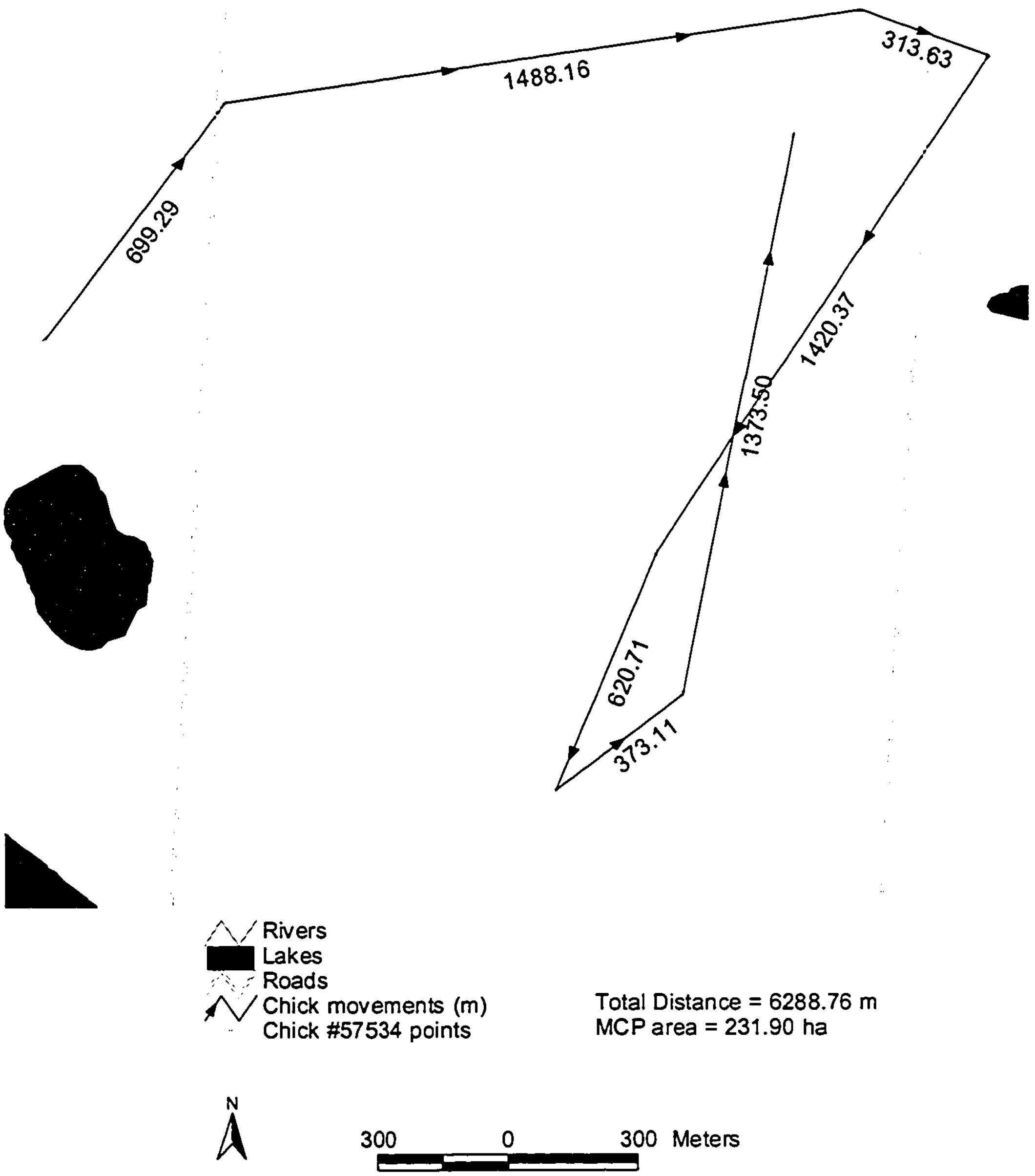


Figure A.6 Movement distances and pattern of radio-tagged chick 57534

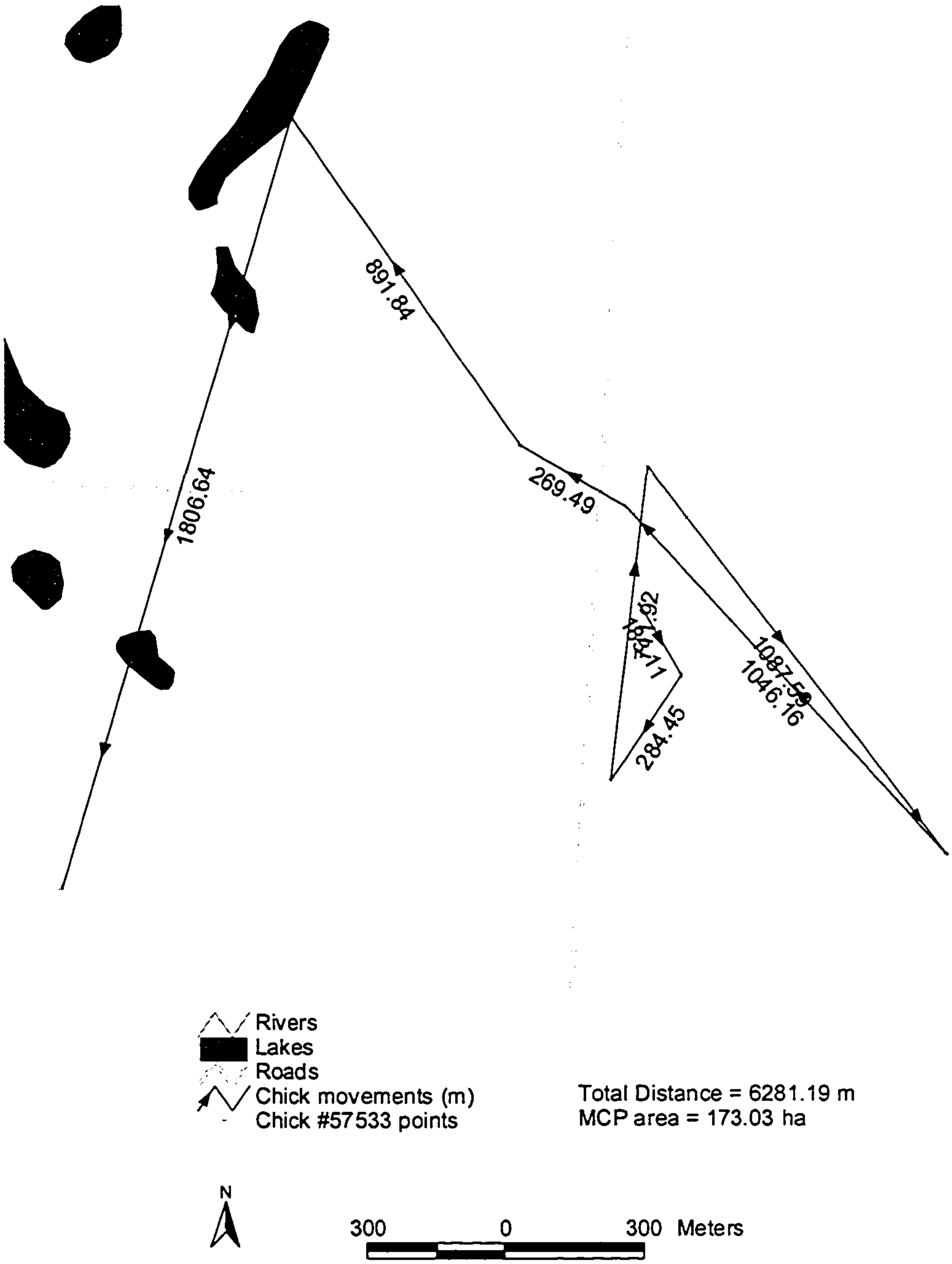


Figure A.7 Movement distances and pattern of radio-tagged chick 57533