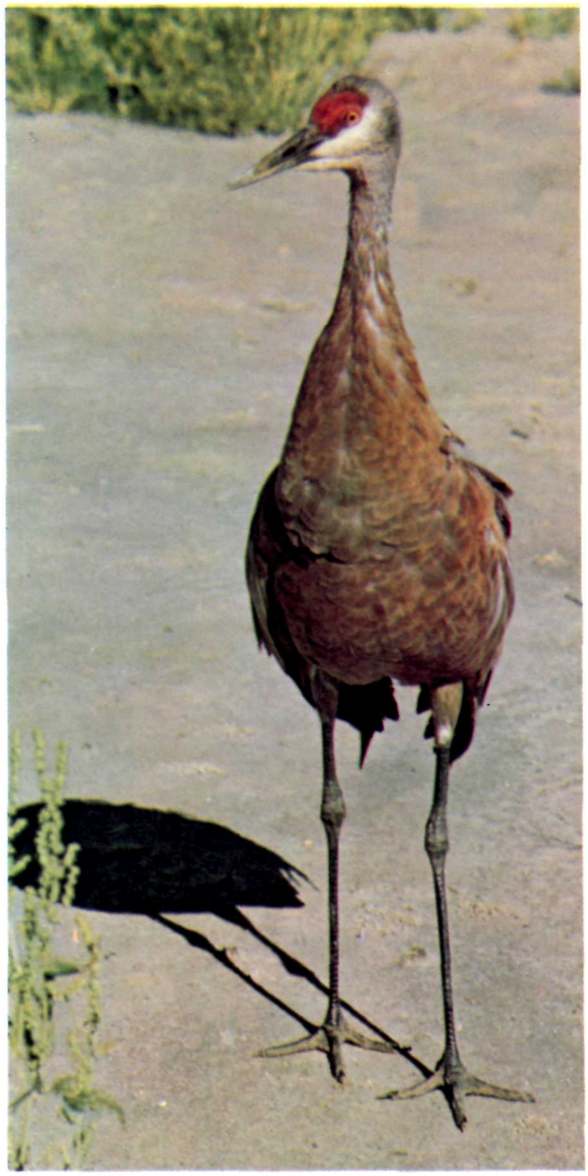
W. J. DOUGLAS STEPHEN



Bionomics of the sandhill crane

CANADIAN WILDLIFE SERVICE REPORT SERIES—NUMBER 2

Bionomics of the sandhill crane

by W. J. Douglas Stephen

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Cover

Top left—Sandhill crane in water.
Top right—Sandhill cranes flying.
Bottom left—Sandhill cranes foraging in a harvested grain field.
Bottom right—Sandhill crane.
All cover photographs taken by John Hatfield, Canadian Wildlife Service, at Last Mountain Lake, Saskatchewan.

Summary

1 Wild populations of legally protected birds such as sandhill cranes and ducks cause damage to commercial crops by consumption and trampling of ripened unthreshed grain. Field studies were carried out from 1961 to 1963 at the north end of Last Mountain Lake, Saskatchewan, on methods of minimizing damage to grain fields, particularly by sandhill cranes.
2 Farms affected by crane damage are scattered in a broad band across the Canadian Prairies. The damage is significant because of its perennial occurrence on farms having low capability for grain production and operating on a low profit margin. The supposed occurrence of a rare subspecies, the greater sandhill crane, and aesthetic considerations prevented hunting of cranes for 46 years, until 1964.
3 Cranes causing damage are on autumn migration. Using established taxonomic criteria, greater sandhill cranes could not be distinguished among autumn or spring migrants at Last Mountain Lake.
4 Autumn migrants arrive at Last Mountain Lake during the first week of August, reach a peak of about 18,000 cranes during the third week of August, and remain near that level until the middle of September. They then decline until the last cranes leave after the middle of October. The average cumulative number of crane-days before threshing is general in the Last Mountain Lake district is estimated to be 350,000.
5 Automatic acetylene exploders produced significant differences in the mean number and mean frequency of occurrence of cranes in treated and untreated quarter sections. The distribution of cranes in grain fields and on roosts was related to the number and duration of treatments and all those factors were related to availability of feeding space, although the total number of cranes in the area was unaffected.
6 Grain was present in the gullets of 93 per cent of 190 shot specimens and food consumption of captive wild cranes indicated that 1 bushel of wheat would supply food for at least 200 cranes for 1 day.
7 The highest number of cranes observed foraging in grain fields was 4,365 per 100 acres, although they were most frequently observed in flocks of 100 or less per quarter section. A mean distance of 5.79 ± 0.1622 (SE) feet was observed between individual cranes foraging in grain fields, but the space occupied by individuals was inadequate to describe fully the observed dispersions of cranes.
8 The estimated minimum foraging requirements of the crane population at Last Mountain Lake would be met by 412 acres if grain fields were less than 100 acres each. Cranes are most likely to forage in grain fields nearest major roosts.
9 The land most susceptible to damage at Last Mountain Lake has low capability for grain production. Prevention of damage with acetylene exploders was estimated to cost $43.83 annually per quarter section. If all susceptible quarters were so treated the total cost would average at least $3,769 annually, but the cost of damage if not treated is estimated to average at least $5,843 annually. Using a combination of acetylene exploders and the supplemental feeding techniques tested in this study, the cost would be reduced to less than $3,225 annually.

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Acknowledgements

This study was carried out as a project of the Canadian Wildlife Service, and the results were presented to the University of Saskatchewan, College of Graduate Studies, Department of Biology, in partial satisfaction of the requirements for the degree of Doctor of Philosophy. My research supervisor, Dr. Richard S. Miller of the Department of Biology, provided guidance with a special mixture of patience and frank criticism. I am indebted to many other persons for stimulation, although Dr. David A. Munro, now Director of the Canadian Wildlife Service; Dr. W.E. Stevens, Western Region Superintendent; and Mr. R.H. Mackay, Western Region Supervisor of Conservation and Development, have created a particular obligation by their encouragement and timely suggestions. Many persons provided technical assistance and their willingness to perform tasks which were sometimes dreary is appreciated. Acknowledgement is due John P. Hatfield for his assistance in field work and particularly for his photographs of sandhill cranes.

The Wildlife Branch of the Saskatchewan Department of Natural Resources provided personnel for technical assistance during this study and allowed use of land under their administration. Mr. S.A. Gardiner of the Navigational Aids Section of the Radio and Electrical Engineering Division of the National Research Council, Ottawa, designed the new acetylene exploder used during this study and provided consultation during the construction and field testing of the prototype. Mr. A.O. Smith, Chief Farm Underwriter of the Saskatchewan Government Insurance Company, assisted by providing access to data on liabilities and claims for sandhill crane and duck damage.

Introduction

Sandhill cranes (*Grus canadensis* Linné) were hunted for food and recreation until 1918, when they were protected by the Migratory Birds Convention Act now administered by the Canadian Wildlife Service. Since then the value of cranes has been primarily aesthetic but they have become unpopular with farmers in western Canada because they consume and trample ripened unthreshed grain. Damage to crops is a problem which arouses public sympathy easily, particularly in the Prairie Provinces where the economy is based on grain growing. The conventional method of dealing with wildlife causing damage is to attempt reduction of their numbers.

However, legislation provides for total protection of many wildlife species; others may be hunted only during open seasons. Populations of any wild animal are maintained for economic, scientific, and moral reasons. The moral basis is the belief that animals should be protected for their own sake, that is, they have rights equal or superior to those of people. The scientific justification is that maintaining natural populations for study will aid in understanding ecological relationships as they apply to the betterment of human welfare. The economic justification is the direct utility of natural populations, ranging from sustenance for native people to recreational hunting and inspiration for poets, painters, and photographers. Elton (1958) points out the indirect economic benefits of maintaining a diversity of species and complex communities as a hedge against the destructive fluctuations which occur in simplified natural environments and agricultural monocultures. However, Elton says "It is no use pretending that conservation of animals for pleasure, or instruction or the assigning of superior rights to animals will ever take precedence over human survival". All of these reasons may be invoked for protection of the sandhill crane population, but the economic arguments arising from farmers' complaints about damage caused by a protected species must be answered. From the viewpoint of some farmers, there are times when too many cranes are in their grain fields.

Even if desirable, eradication or reducing the numbers of a species is not always feasible. Biological resistance of survivors, deleterious side effects within biotic communities, and environmental pollution frequently result from direct control methods (Elton, 1958; Carson, 1962). Shooting, advocated by farmers, does not have the far-reaching ecological effects of a chemical poison program but has not been effective, for example, in reducing damage by ducks. As cranes forage in flocks, are migratory, and stop for extended periods at certain places during migration, it is apparent that drastic reduction of the population would be required to achieve relief from damage. Even the last one thousand cranes might cause significant losses in many crops along the migration route.

Shooting of sandhill cranes also presents some special problems. Sandhill cranes were protected from hunting in 1918 because they were thought to be in danger of extinction. Although the species is presumed to have increased in number since then, the present population and its rates of change are not well known, so that the effects of shooting cannot be easily predicted. Objections to a hunting season for sandhill cranes were raised over a period of time because of the reported presence in western Canada of the rare greater sandhill crane (*Grus canadensis tabida*) (Bent, 1926; Ridgway and Friedmann, 1941; Walkinshaw, 1949; and Munro, 1950), and the difficulty of distinguishing it from the lesser sandhill crane (*Grus canadensis canadensis*). In addition, the rare whooping crane (*Grus americana*) occasionally occurs among flocks of sandhill cranes. Juvenile whooping cranes have brown plumage which might be confused with that of the sandhill crane, although the adults are likely to be distinctive because they are larger and white. In view of the legal mandate to protect the sandhill and the whooping crane, and the conformity of the law to an ecological rationale, this study was initiated to find a solution to the problem of damage to grain crops by sandhill cranes, a solution that would not require reducing their numbers.

The specific objectives of this study were as follows: (1) to estimate the distribution and extent of crop damage by cranes in the Prairie Provinces; (2) to investigate sandhill crane populations, their seasonal and daily movements, and their numbers relative to the susceptibility of grain crops to damage; (3) to test acetylene exploders as a means of limiting areas used by sandhill cranes; (4) to test supplementary feeding areas in combination with acetylene exploders as a means of preventing damage; (5) to estimate the food and space requirements of sandhill cranes; and (6) to consider the economic implications of sandhill crane damage and its control.

The general problem of damage to crops caused by game animals has been neglected, primarily because of opposition to reduction of their numbers (Eadie, 1954). The opposition is related to public interest in hunting and natural history which has existed since earliest times and has broadened. As modern agricultural technology has developed, major crop production problems have been solved, land use has been intensified, and the conflict of interest which is associated with wildlife damage to crops has also intensified. The problem to grain growers in western Canada caused by game birds, particularly sandhill cranes and ducks, and the need for a solution other than reduction of natural populations, has been recognized by various writers (Soper, 1948; Munro, 1950; Colls, 1951; Leitch, 1951; Mair, 1953; Munro and Gollop, 1955; Paynter, 1955; Anonymous, 1959; Harper, 1959; Anonymous, 1960; Ledingham, 1960; Green, 1961; Hammond, 1961; Munro, 1961; Walkinshaw, 1961; Wright, 1961; Anonymous, 1963; and Roley, 1963). There is, however, very little literature on sandhill crane populations, their foraging requirements and effect on the environment. Most of the information available was summarized by Walkinshaw (1949).

Taxonomic status

The sandhill crane is a large, plump-bodied bird with a long neck and long legs on which the hind toe is elevated. In flight the neck is extended. The bill is long and straight with a lateral groove in which the nostrils are situated but there is no septum. The trachea is convoluted in the sternum. In the adults of both sexes the forehead is red, bare skin of a warty texture with a few short, hair-like feathers (see Fig. 8). The plumage is predominantly grey with a white throat and black primary feathers, but may appear brown because of adventitious rust stains (Taverner, 1929). In juveniles the plumage is naturally brown and the head is fully feathered.

The most recent classification (Peters, 1934) places the sandhill crane in the Family Gruidae, Order Gruiforms. Peters recognized four subspecies,[1] the lesser sandhill crane (*G. c. canadensis*), the greater sandhill crane (*G. c. tabida*), the Florida sandhill crane (*G. c. pratensis*), and the Cuban sandhill crane (*G. c. nesiotes*). Walkinshaw (1949) distinguished those subspecies on the basis of length of tarsus, length of exposed culmen, colour of the shafts of primary feathers, and colour of the hind neck and occiput.

The distribution of sandhill cranes was reported by Walkinshaw as follows:

> There is a gradation in size of sandhill crane specimens from the small forms of the Arctic (*canadensis*) to the large form of the northern United States (*tabida*—the greater sandhill crane). Specimens from central Alberta, Saskatchewan, and Manitoba are intermediate: the majority are definitely *tabida* but some are closer in measurements to *canadensis*.
>
> The Florida sandhill is resident in southeastern Mississippi, and from southern Georgia into Florida as far south as the Everglades.
>
> The Cuban sandhill is resident in the western portion of Cuba and the Isle of Pines (*sic*).

Migratory populations

The breeding range of the migratory sandhill cranes (*G. c. canadensis* and *G. c. tabida*) extends from the Canadian and Russian Arctic to northern California, Nevada, Utah, Wyoming, Idaho, British Columbia, Alberta, Saskatchewan, Minnesota, Wisconsin, and Michigan (Walkinshaw, 1949). Although there are no recent published records of cranes breeding in Manitoba, I have observed adults there in summer, and cranes with young have been reported in southeastern Manitoba (E. F. Bossenmaier, pers. comm.). Sandhill cranes winter from central California, east to Texas and south into Mexico. The relationship between breeding and wintering ranges of the various segments of the population is not known, although there is some evidence that cranes from Michigan may winter in southeastern United States (Walkinshaw, 1949, 1960).

Although continuous records of the total crane population are not available, occasional counts of concentrations of migratory cranes indicate minimum populations. There were an estimated 100,000 sandhill cranes at Horseshoe Lake, near Dawson, North Dakota, on October 13, 1930, and more than 100,000 sandhill cranes were observed and photographed along the Platte River near Hershey, Nebraska, during the spring of 1943 (Walkinshaw, 1949). On November 25, 1963, the sandhill crane population in west Texas and eastern New Mexico was estimated to be 207,000. During spring surveys of the Platte River, Nebraska, in the 6-year-period 1959–64 a mean of 135,000 cranes was estimated (letter July 29, 1964, from R.J. Buller, U.S. Bureau of Sport Fisheries and Wildlife, Albuquerque, New Mexico). Large migrant flocks are not seen in Michigan, Florida, or Cuba (Walkinshaw, 1949). In 1944 the breeding population in Michigan was

[1] Walkinshaw (1965) has recently described a new subspecies, the Canadian sandhill crane (*G. c. rowani*) based on specimens from Alberta, Saskatchewan, west-central Manitoba, and southern Mackenzie district.

estimated to be 27 pairs. In 1942 the entire Florida crane population was estimated at 2,650 individuals and the Cuban crane population at even less (Walkinshaw, 1949).

The total sandhill crane population is apparently comprised of several groups: those resident on Caribbean islands; those resident in the southeastern United States; those breeding in Michigan which apparently migrate to the southeastern United States; and those which migrate from the southwestern United States and Mexico to the northern United States and Canada and comprise the majority of the sandhill cranes. Obviously the cranes of interest in this study are those which winter in the southwestern United States and in Mexico.

The sandhill crane populations wintering in southwestern United States and in Mexico begin to migrate northward in late March (Walkinshaw, 1949). They pass through the Canadian Prairies in April. The spring migration through Saskatchewan, from April 15 to May 10, proceeds in a northwesterly direction along two routes; the main route touches Last Mountain Lake, Quill Lakes, Lake Lenore, Sandwith, Midnight Lake, and Meadow Lake and the other route passes over Yorkton, Arborfield, and Nipawin (Munro, 1950). Few cranes are seen in summer in Saskatchewan or elsewhere on the Canadian Prairies. Autumn migration is more dispersed and less continuous than in spring. Flocks numbering in the thousands may be seen in favourable feeding areas from late August to early October (Munro, 1950). The autumn migration of sandhill cranes coincides with the grain harvest on the Canadian Prairies.

Last Mountain Lake populations

Munro's (1950) report of observations of sandhill cranes during August and September 1947 is the only published account of the feeding habits and daily movements of sandhill cranes on the Canadian Prairies. He estimated the number of cranes arriving at night resting areas at the north end of Last Mountain Lake, Saskatchewan, examined the stomach and crop contents of four specimens, and studied feeding habits by observing cranes. The resting areas used by cranes include beaches and native prairie adjacent to beaches on the peninsula and islands at the north end, and on a peninsula about 8 miles south on the east side of the lake.

Daily activity

During the half hour preceding and the half hour following sunrise, cranes leave their overnight roosting areas and fly to feeding grounds. They return to resting areas at midday, but use a greater variety of roosts at noon than at night. Most cranes again fly to feeding grounds in the early afternoon. The cranes return to their night roosts during the half hour preceding and the half hour following sunset (Munro, 1950).

Departures of sandhill cranes were recorded from three roosts in the southern United States on five evenings and four mornings during the winter of 1944. Time from first departure to last departure totalled as little as 25 minutes and as long as 85 minutes (Walkinshaw, 1949). The earliest departure was 38 minutes before sunrise and latest was 66 minutes after sunrise. Departures were observed most frequently in the half hour following sunrise. First arrivals on the roosting area at night were recorded 2 hours and 20 minutes before sunset and the last arrivals 20 minutes after sunset, with most arriving in the half hour preceding sunset. The observations of Walkinshaw (1949) and Munro (1950) indicate consistent times of leaving and arriving at night roosts.

Cranes were reported leaving night roosts for fields in groups of 1 to 120, and returning to night roosts in groups of 2 to 800 (Walkinshaw, 1949). At midday, cranes were reported to return to roosts in groups of 10 to 100 (Munro, 1950). The information on structure of foraging flocks is limited, but size of flocks leaving roosts and returning indicates that cranes forage in small groups and that some aggregation takes place before they return to roosts in the evening.

Munro (1950) stated that feeding areas were generally not more than 2 miles from water, although Walkinshaw (1949) reported groups of 2 to 200 cranes on grain fields at distances from ½ to 10 miles from roosts in Texas and New Mexico in winter. From observations of nine flocks of 2 and 3 cranes in fields ½ to 1½ miles from roosts, and eight flocks of 6 to 45 cranes in fields ⅔ to 3 miles from roosts, Walkinshaw concluded that in early autumn small "family groups" feed in separate fields but in late September or early October these form larger flocks. Although Walkinshaw stated that in the late autumn cranes fly farther at times than these 17 groups, 22 feeding areas used in late autumn in Michigan were reported at distances of ½ to 2 miles from roosts. The information on location of feeding areas in relation to roosts is limited and not consistent.

Feeding takes place in grain fields, on fallow land, and in pastures (Munro, 1950). About 20 per cent of the 12,000 crane occurrences observed by Munro were recorded in unthreshed grain crops susceptible to damage. Walkinshaw (1949) describes feeding areas as open grain fields or open pastures, and notes that "dancing" of cranes also occurs in grain fields. The function of dancing behaviour is unknown, but it indicates that activities other than feeding cause damage. Use of cultivated fields is characteristic of the Family Gruidae (Blyth and Tegetmeier, 1881; Blaauw, 1897). Sandhill cranes were reported feeding in cultivated fields in Mississippi as early as 1821 (Audubon, 1835 *fide* Walkinshaw, 1949 and Ford, 1957) and have long been associated with grain fields in California and Mexico (Walkinshaw, 1949). Damage to grain in the Prairie Provinces by cranes was reported in the early 1920's (Clark, 1923; Taverner, 1926). It seems likely that damage has occurred there since the beginning of grain cultivation in crane habitats.

Food habits

Each of four sandhill crane specimens examined by Munro (1950) contained wheat. Grain comprised 54 per cent of the total wet volume of the stomach and crop contents and insects and grit the remainder. Walkinshaw (1949) reported that in addition to grain, sandhill cranes eat roots, tubers, seeds, berries, leaves of a variety of plants native to different parts of their ranges, and animal material such as grasshoppers, beetles, cutworm pupae, other insects, snails, tadpoles, frogs, lizards, snakes, nestling birds, birds' eggs, and small mammals.

Hamerstrom (1938) examined 30 fresh crane fecal pellets collected from a buckwheat field in Wisconsin in September 1936. Buckwheat hulls and seed coats made up 81.9 grams of the 82.8 grams of the air-dried material. Seeds of huckleberry (*Gaylussacia baccata*) and blueberry (*Vaccinium* sp.), fragments of wings and legs of grasshoppers (*Melanopus femur-rubrum*), and the legs and elytra of unidentified beetles (*Coleoptera*) made up the remainder. Tanner (1941) examined about 70 crane fecal pellets collected from a field of flax and sweet clover in Minnesota in October 1940. The 230 cc. air-dried sample contained 217 cc. corn hulls and fragments of kernels, 10 cc. of sweet clover leaves (*Melilotus* sp.), 3 cc. of flax seeds, seed pods, and flower stalks, traces of oat hulls, legs and body fragments of grasshoppers (*Melanopus* sp.), a single seed of foxtail (*Setaria* sp.), a small unidentified snail shell, the abdomen of an unidentified insect, unidentified twigs, and an unidentified object, probably an insect pupa case. To summarize, cranes forage predominantly on grain fields if available, although a variety of foods may be eaten. Flights from roosts to fields within range take place daily. Damage is caused when the fields used for foraging are unharvested.

Crop damage

Munro (1950) did not observe damage by cranes in excess of 20 per cent of a crop value in 1947 although he reported that in 1946 some farmers claimed losses as high as 50 per cent. Walkinshaw (1949) reported that cranes fly directly to feeding areas from the roost, and often use the same feeding area for several days or even longer, but are wary while feeding and will fly into a more remote field if disturbed. Munro (1950) stated that scarecrows and shooting were used by farmers. He tested one acetylene exploder as a means of controlling crop damage but concluded that it was unsatisfactory because it made little noise and was undependable (pers. comm.). Some farmers considered scarecrows helpful in controlling damage but others considered them completely useless. Shooting scared cranes and was a good method of controlling damage but was costly in man-hours during harvest and merely drove cranes from one field to another (Munro, 1950).

All-risk crop insurance underwritten by the Federal Government is available to farmers in the Prairie Provinces, and provincially sponsored insurance against specific wildlife risks may be obtained by farmers in Saskatchewan and Alberta. Munro (1961) discussed research by the Canadian Wildlife Service on control of damage by sandhill cranes and mentioned the present study. No other published accounts of attempts to control or compensate for sandhill crane damage are available.

Although more information on crane populations and their behaviour was needed it seemed at the outset of this study that methods for controlling duck damage might be applied to crops susceptible to crane damage. Sirens (Thiessen *et al.*, 1951); a combination of detection patrols, scarecrows, and gunfire (Hochbaum, Dillon, and Howard, 1954; Bossenmaier and Marshall, 1958); and acetylene exploders (Stephen, 1961) have been used to control or reduce duck damage on the Canadian Prairies. A combination of feeding and scaring treatments as used to control duck damage in the states of California and North Dakota (Horn, 1949; Biehn, 1951; Scouler, 1952; Lostetter, 1956 and 1960; and Hammond, 1961) seemed to be the most effective. Of the variety of scaring devices used, a redesigned acetylene exploder seems to offer the best combination of economy and effectiveness (Stephen, 1961).

Methods and materials

Munro (1950) said that crane damage was severe in the farming district around the north end of Last Mountain Lake. Complaints received by federal and provincial government representatives at a public meeting called by farmers on September 13, 1959, at Lake City School near Imperial, Saskatchewan, confirmed that finding.

Study area

The north end of Last Mountain Lake, Saskatchewan, was chosen as the focal point of this study as it was apparent that damage control treatments could be tested in the vicinity. It seemed desirable that the area selected for experiments should have easily recognizable boundaries and include most of the fields that might be frequented by cranes. Munro (1950) observed that cranes were usually in fields not more than 2 miles from water. Consequently townships[1] 27, 28, and 29 in ranges 22, 23, and 24 west of the second meridian were chosen as a study area. These nine townships comprise a block 18 miles square (Fig. 1). The lake extends northward about 11 miles from the western border of the study area, and southward and slightly easterly about 45 miles from the study area. Locally the lake is often called "Long Lake" as it seldom exceeds 2 miles in width. The lakeshore is steep in the southern and central portion of the lake and flat and shallow in the northern portion. The flat shores and shallow water sheltered by islands and in bays provide resting places for cranes and other birds.

The value of the area to birds was recognized early. While Saskatchewan was still part of the Northwest Territories, 2,500 acres "were reserved from sale and settlement, and set apart as breeding grounds for wild fowl" along the shores of the northernmost 17 miles of Last Mountain Lake (Order in Council of Wednesday June 8, 1887, Chapter 54, Revised Statutes of Canada, "The Dominion Lands Act"). The area was named the Last Mountain Lake Bird Sanctuary, and included under the Migratory Birds Convention Act in 1921. In 1930 this land was transferred to provincial administration, although the federal Migratory Birds Convention Act still applies.

Settlement and development of agriculture within the study area in the early 1900's were associated with use of Last Mountain Lake as a transportation route for land-seekers and supplies prior to road and railway construction (Elderton, 1960). Steamboat navigation on the lake was discontinued in 1913 (Bocking, 1960), but the remnants of Watertown, the northern terminus, are still visible. The towns of Govan, Imperial, Nokomis, and Simpson are settlements and trading centres for the present agricultural community.

The general feature of the landscape is predominantly cultivated land lying in the transition zone between grassland and forest. Typically, clumps of trembling aspen (*Populus tremuloides*) and willow (*Salix* sp.) grow in moist locations, with buckbrush (*Symphoricarpos* sp.), rose (*Rosa* sp.), and wolf willow (*Elaeagnus* sp.) pioneering on the uncultivated upland. Most of the farmsteads are surrounded by planted windbreaks, and several field hedgerows of *Caragana* sp. have been planted to prevent wind erosion. Animals characteristic of the transition zone between grassland and forest regions are common (Hatfield, 1964), but the most notable feature of the native fauna is the variety and abundance of both migratory and resident birds.

The soils and topography within the study area have been mapped by Mitchell, Moss, and Clayton (1944). The topography is classed as predominantly gently to moderately undulating. Small portions in the northeast and southeast are rolling, and a small portion in the centre of the study block near the northern edge is flat to depressional. Soil texture is light, varying from loam to light loam, fine sandy loam, and sandy loam. There are also extensive alkaline areas.

In the cultivated portion of the study area (Fig. 1) the predominant crop is wheat although other small grains such as barley, oats, and rye are grown, as well as flax, rape, mustard, and sunflowers. In the uncultivated portion, haying and grazing of native vegetation are the predominant land uses. There are a few parcels of improved pasture.

Aside from a commercial fishery operation, other important uses of land in the study area are associated with outdoor recreation. Along the lakeshore within the study area there are two active beach developments and vestiges of two others as well as several isolated cottages and many boat houses. Naturalists and photographers are

[1] Townships are administrative land units, usually 36 square miles in area, 6 miles to a side. The term township is also applied to the 6-mile increments numbered northward from 49° north latitude. The term range is applied to the 6-mile increments numbered westward from selected meridians of longitude. The second meridian is 102° west longitude. The terms township and range with reference to a meridian serve as legal descriptions of land units known as townships.

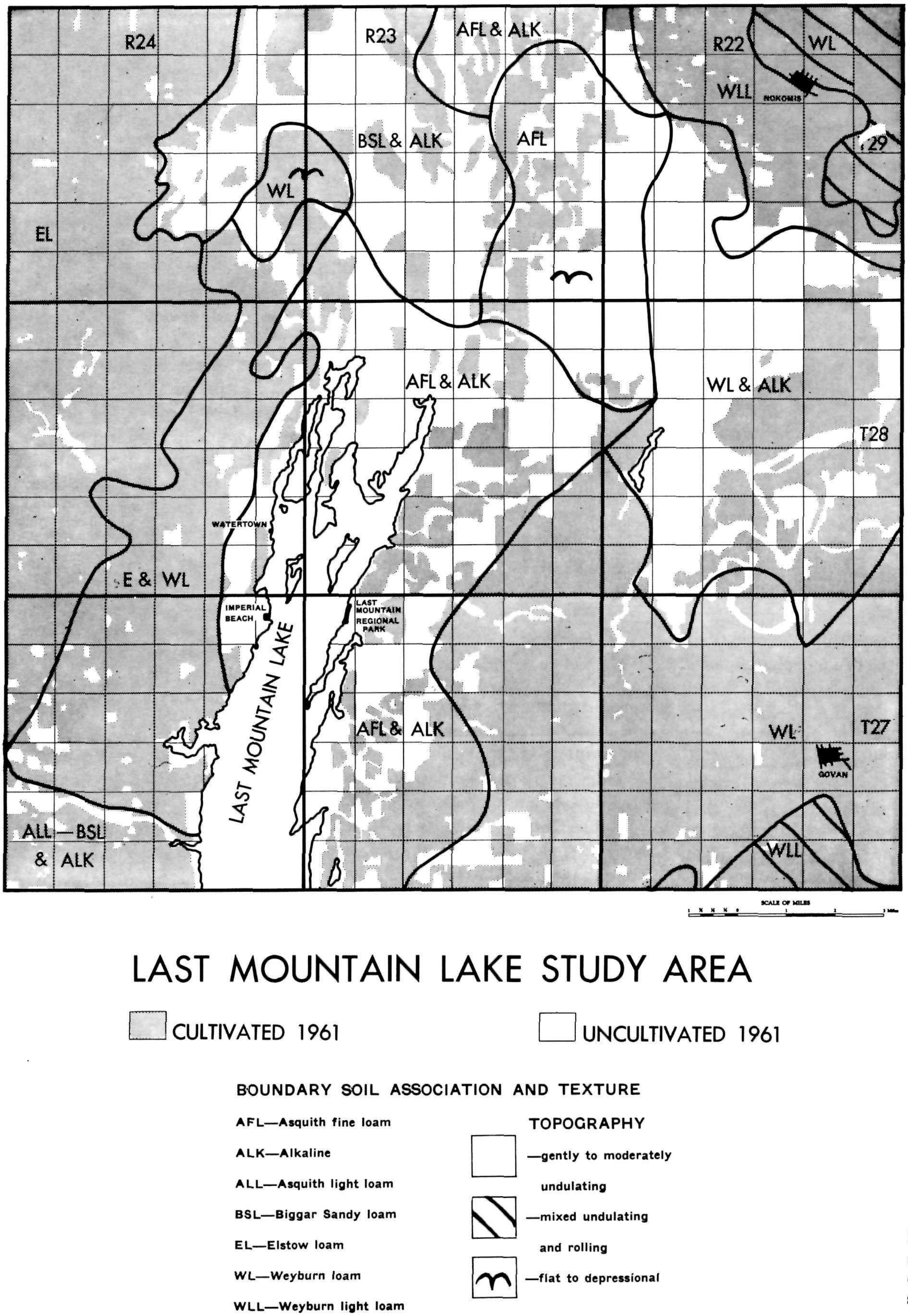


Figure 1 **Last Mountain Lake study area showing boundaries, cultivated and uncultivated land, soil associations and texture.**

attracted to the area by spectacular congregations of birds. Sharp-tailed grouse and Hungarian partridge are hunted in uncultivated areas and associated grain fields, and ducks and geese are hunted both in grain fields and in strategic locations near the lake.

Experimental procedures

The acetylene exploder

Acetylene exploders ignite a controlled amount of acetylene (C_2H_2) and air mixture to cause an explosion. The noise of the explosion caused by

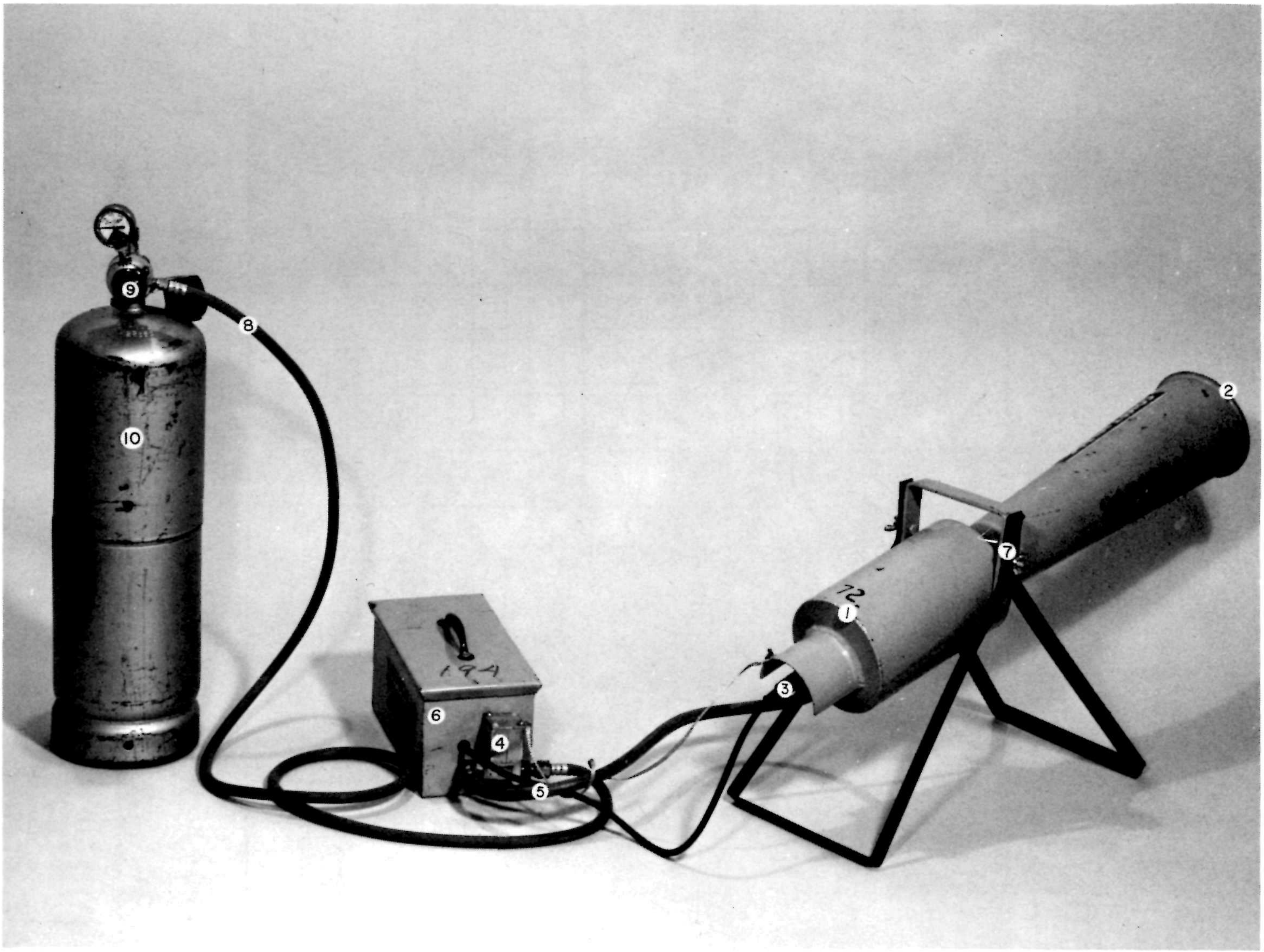


Figure 2 **An acetylene exploder of the type used, showing explosion chamber (1), megaphone (2), spark plug (3), Solenoid valve (4), connecting hose and wire (5), timer box (6), stand (7), acetylene supply hose (8), pressure regulator (9), and acetylene cylinder (10).**

machines used in this study is similar to that of a large-bore rifle or shotgun. Following an earlier study (Stephen, 1961), it was recommended that a machine be designed with improved dependability, an electric ignition system, and accurate timing of explosion intervals. Working models of new exploders were designed and produced in the Mechanical Engineering Department of the University of Saskatchewan and the Navigational Aids Section of the Radio and Electrical Engineering Division, National Research Council, Ottawa. The model designed in Ottawa was selected. Machines for the 1961 field tests were built in the Saskatoon Laboratory of the Canadian Wildlife Service and served as prototypes for acetylene exploders manufactured by the Smith-Roles Company, Limited, Saskatoon, Saskatchewan. The first production models of the Smith-Roles exploders were used for experimental treatments in 1962 and 1963.

The basic components of the exploders used in this study (Fig. 2) were an explosion chamber with a megaphone, a spark plug, a solenoid valve, timers for cycling interval and daily operation, and an acetylene supply. The explosion chamber and megaphone were supported on a stand apart from the acetylene supply and the box containing the timers. The spark plug, solenoid valve, and timers were energized by electric current supplied from eight 1.5-volt dry cells and two 67.5-volt dry cells contained in the box with the timers. Acetylene was supplied from 40-cubic-foot cylinders through a pressure regulator.

The exploders were placed in fields and on roosts at a density of one per quarter section. Each machine was preset to operate at one explosion per minute. Whenever possible, the exploders were placed in fields where the cranes had evidently been feeding. In standing crops the exploders were usually placed at the edge of the field toward the lake, as it was thought that the noise of the exploder might be muffled by grain standing in front of the megaphone. In swathed crops the exploders were placed between the swaths with the megaphone pointed in the direction of the lake. In treatments of roosts, exploders were placed in a dry location with the megaphone pointed in the direction of the roost.

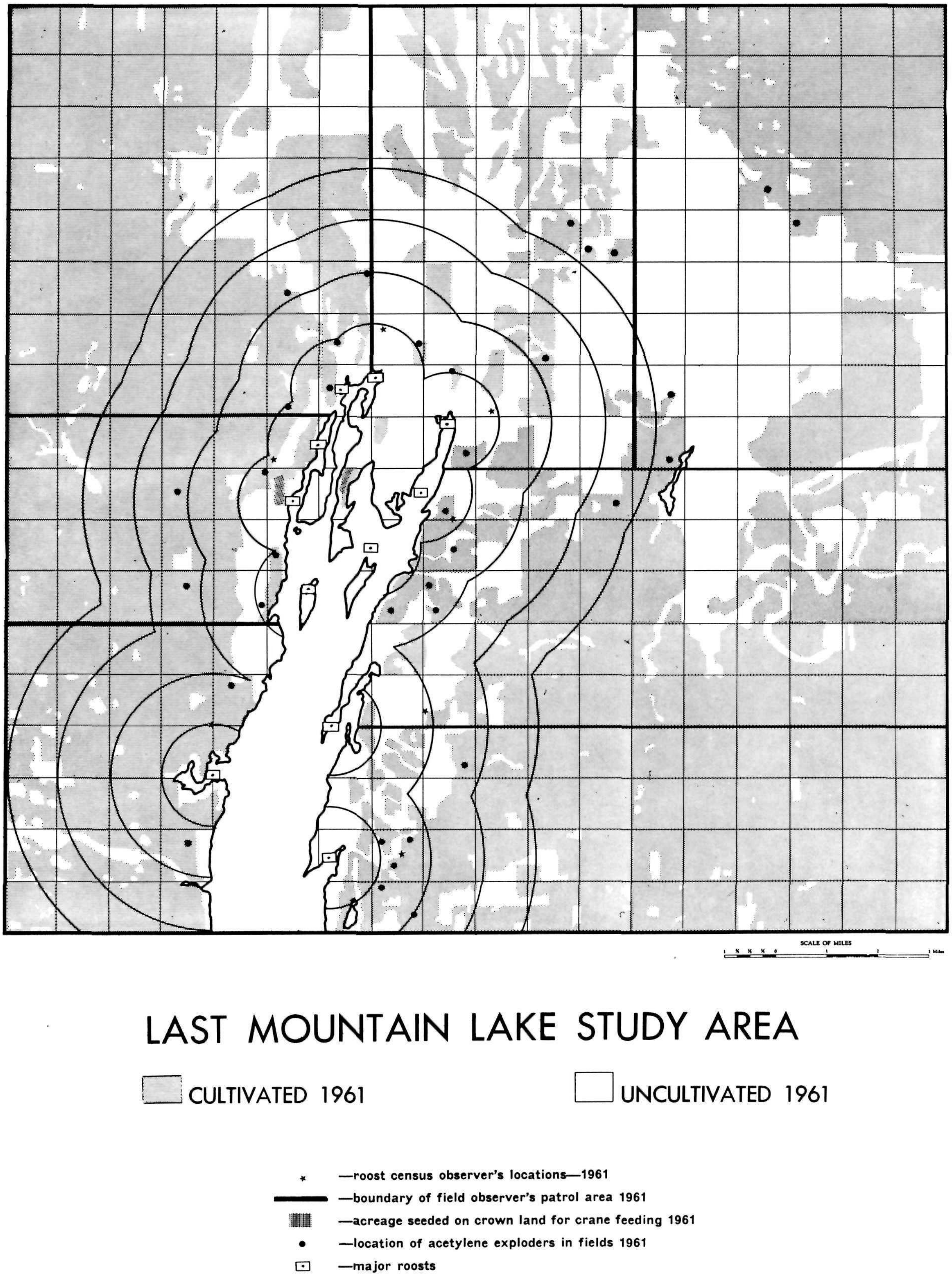
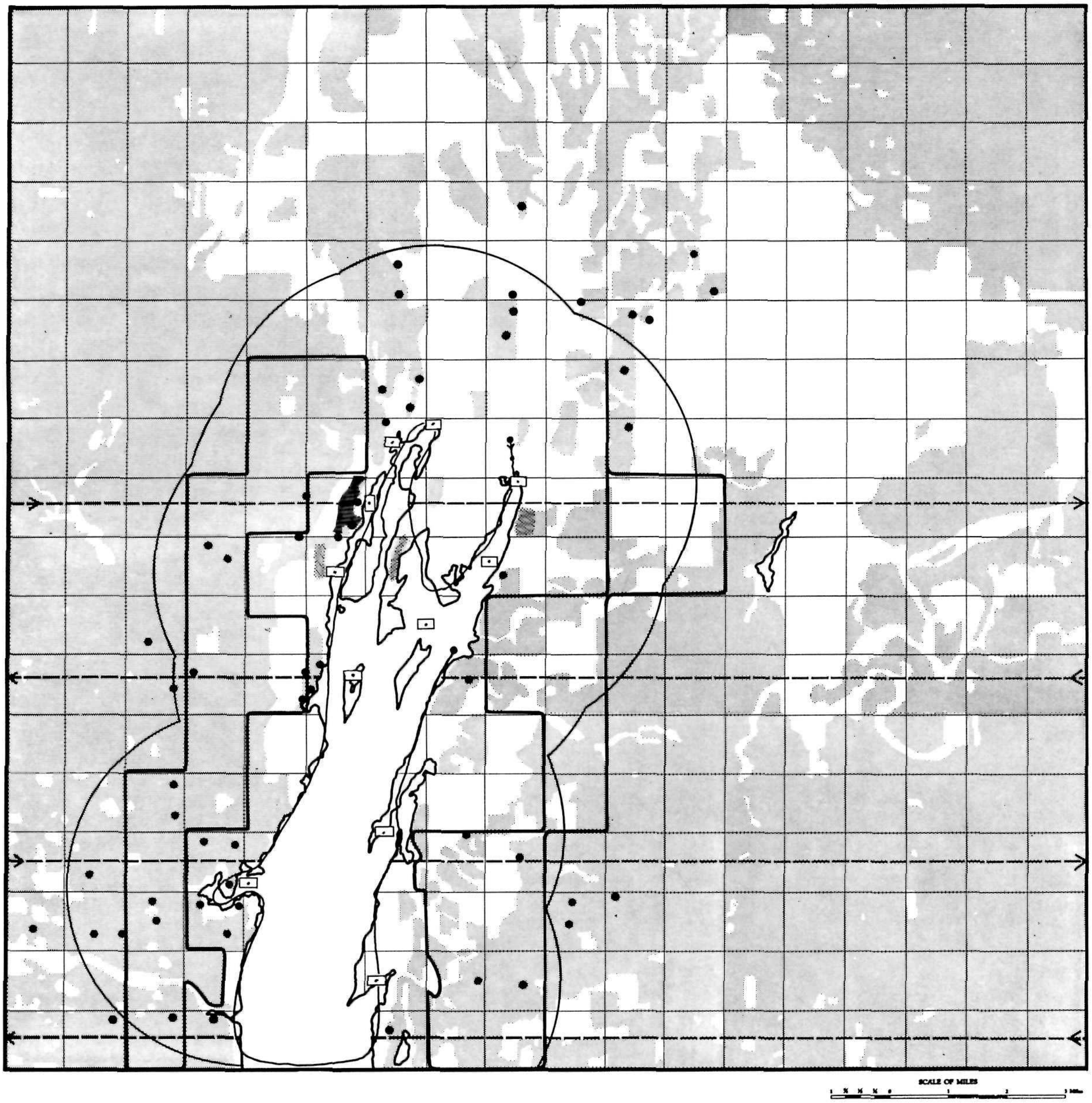


Figure 3 Last Mountain Lake study area showing 1961 locations, patrol areas, exploders, supplementary feeding areas, major roosts, and observers' locations during counts of flocks leaving roosts.

Population survey

Observations were made to detect fields used by cranes and to determine the effect of the exploders. In 1961 observers patrolled all roads and trails in automobiles. A technician was assigned to each of seven approximately equal areas which were patrolled during the 4 hours following sunrise and the 4 hours preceding sunset. The boundaries of the patrol areas are shown in Figure 3. The observers recorded the location and number of cranes seen on each patrol. Maximum counts of cranes observed in each location during each patrol were used in analyses as it was apparent that cranes were moving into fields from roosts during 1961 patrols.



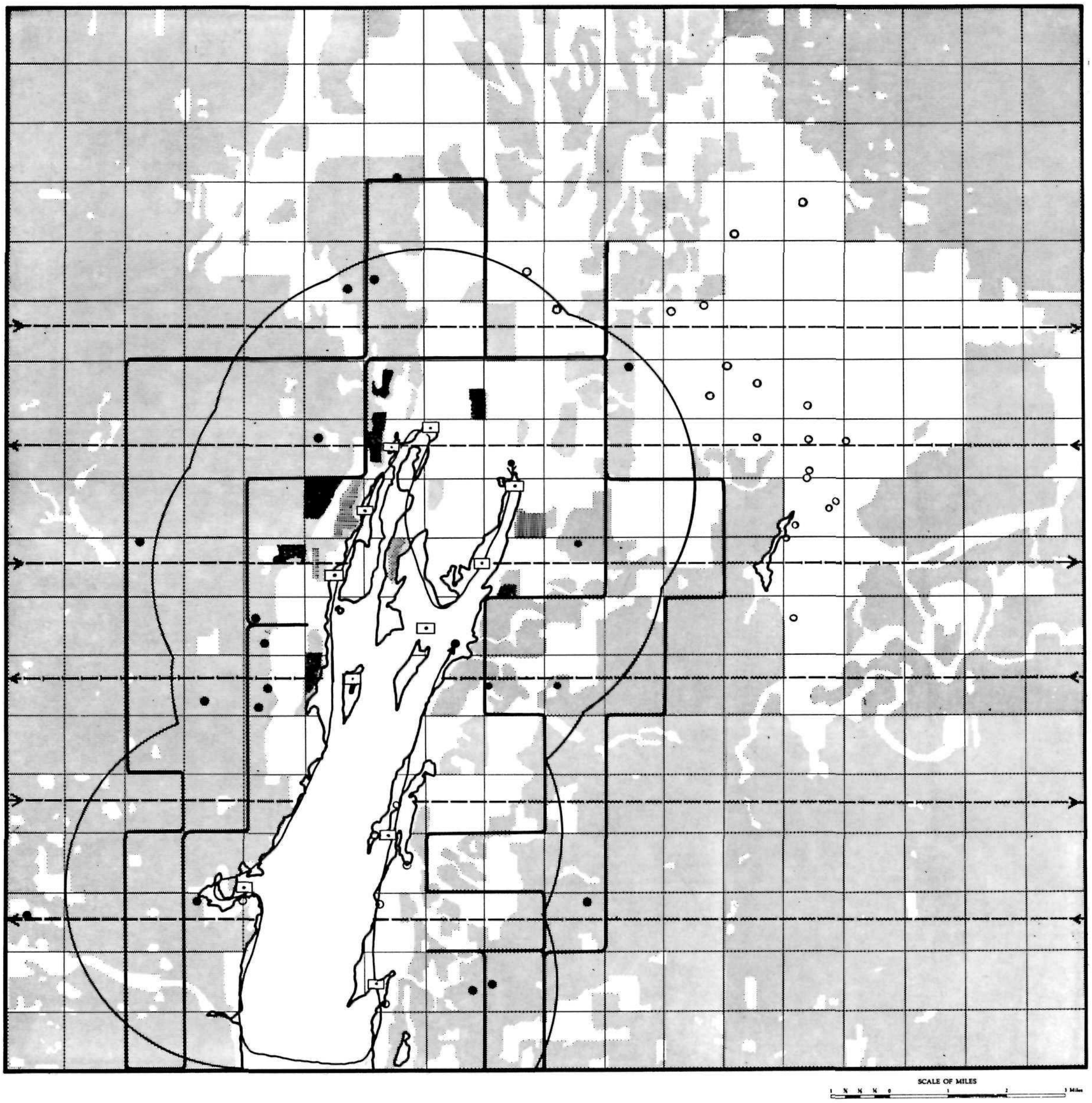
LAST MOUNTAIN LAKE STUDY AREA

CULTIVATED 1961 UNCULTIVATED 1961

—roost census aerial route 1962
—field census aerial route 1962
—field census route of ground patrols 1962
—location of acetylene exploders fields 1962
—three mile limit from major roosts
—major roosts
—acreage seeded on crown land for crane feeding 1962
—acreage commercial grain crops purchased for crane feeding 1962

Figure 4 Last Mountain Lake study area showing 1962 locations of aerial census routes, ground patrols, acetylene exploders, supplementary feeding areas, major roosts, and limit of 3 miles from major roosts.

In 1962 and 1963 the area of ground patrols was reduced and some observations were made along transects from an aircraft. Ground patrols were made along designated routes within 3 miles of Last Mountain Lake (Figs. 4, 5). Patrols were conducted twice daily, beginning ½ hour after sunrise and 3 hours before sunset, and each patrol required about 2½ hours to complete. Patrols were begun from the same point and traversed in the same direction for all observations. One team of observers recorded the numbers and locations of sandhill cranes observed on the east side of the lake and another team patrolled the west side. Locations of cranes on cultivated or uncultivated land were



LAST MOUNTAIN LAKE STUDY AREA

CULTIVATED 1961 — UNCULTIVATED 1961

—roost census aerial route 1963
—field census aerial route 1963
—field census ground patrols 1963
—location of acetylene exploders—fields 1963
—location of acetylene exploders—roost 1963
—three mile limit from major roosts
—major roosts
—acreage seeded on crown land for crane feeding
—acreage of commercial crop purchased for crane feeding
—acreage under contract for crane feeding

Figure 5 Last Mountain Lake study area showing 1963 locations of aerial census routes, ground patrols, acetylene exploders, supplementary feeding areas, major roosts, and 3-mile limit from major roosts.

plotted by reference to maps compiled from aerial photographs.

Locations of aerial transects used in 1962 and 1963 are shown in Figures 4 and 5. The aircraft was flown at an altitude of 300 feet and air speed of about 85 miles per hour. In 1962 the observer accompanying the pilot was W. J. D. Stephen and in 1963 J. P. Hatfield. Numbers and locations of cranes along the transects were recorded.

In 1961, observations of cranes in lure crops (Fig. 3) were made as part of the regular patrols, but in 1962 and 1963 more detailed observations were made. In 1962 observers hid in hay-bale blinds located near the lure crops seeded on crown land. In 1963 two wooden towers were constructed so that detailed observations could be made of two crops from one tower and one crop from the other, while the fourth crop was viewed from a granary located beside it. Observations were made for 5 hours in the morning beginning at sunrise, and 6 hours in the afternoon ending at sunset.

Results

Survey of crop damage

Insurance against damage to crops by cranes, ducks, geese, deer, elk, antelope, and bear was instituted in Saskatchewan in 1953 (Paynter, 1955). During the first 3 years that insurance was available few policies were sold and all indemnities paid were for ducks and big game, but in 1956 the Saskatchewan Government Insurance Company paid two indemnities totalling $1,019.10 for damage by sandhill cranes. The mean value paid for 97 claims in the 5-year-period 1956–1960 was $356.28 (Table 1).

TABLE 1 Value of indemnities paid for sandhill crane damage by Saskatchewan Government Insurance Company

Year	Value of indemnities paid, $	Number of indemnities	Mean indemnity value, $
1956	1,019.10	2	509.55
1957	7,507.08	17	441.93
1958	3,205.75	17	188.57
1959	15,852.61	41	386.65
1960	6,974.25	20	348.71
Pooled	34,558.79	97	356.28

The amounts were based on areas varying from 20 to 160 acres, as all of a crop of one kind in a quarter section had to be insured, and the minimum acreage that could be insured was 20 acres. Most insurance indemnities were paid for crane damage to grain crops near the north end of Last Mountain Lake and, to a lesser extent, around the Quill Lakes (Fig. 6). Similar insurance was offered in Alberta beginning in 1962.

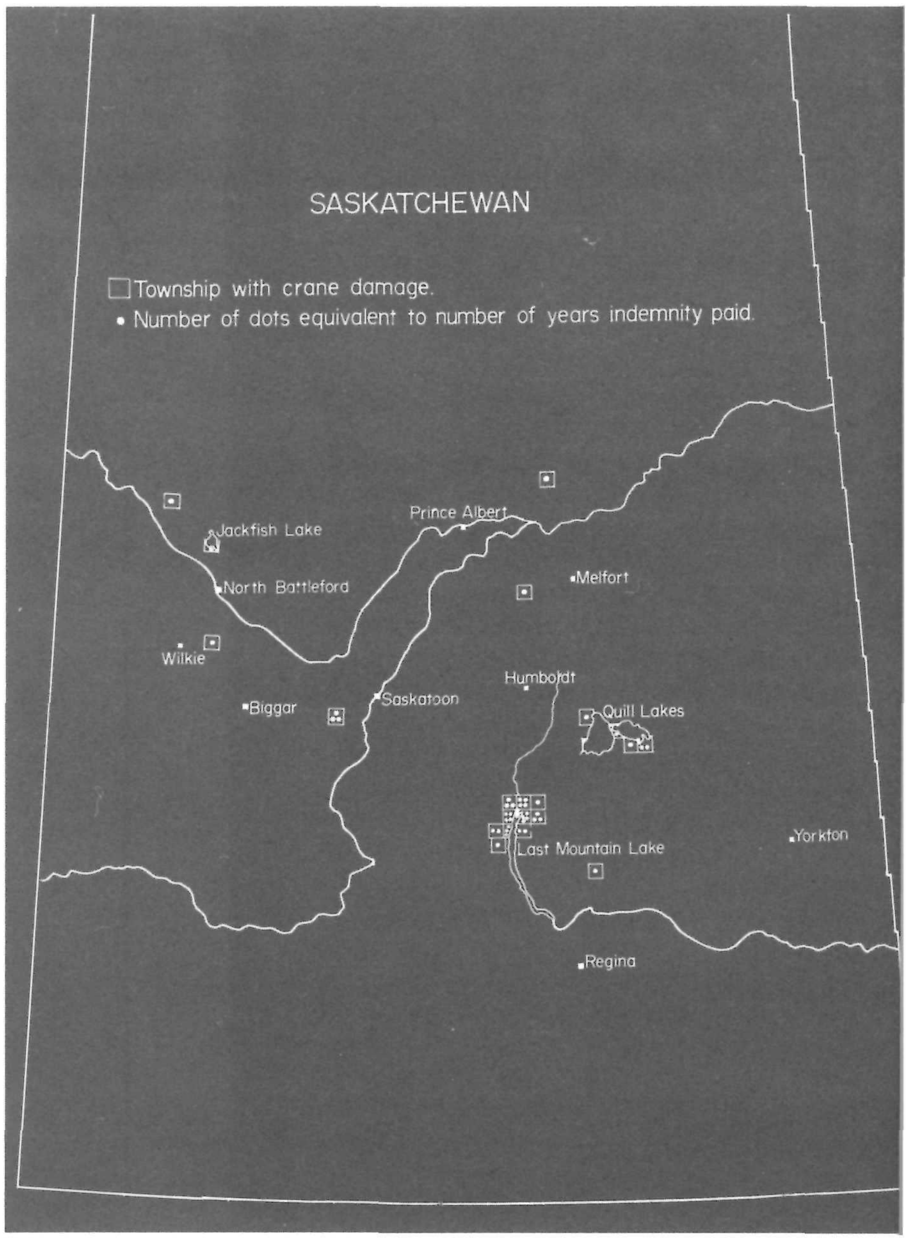
To assess the extent and distribution of sandhill crane damage to grain crops in the Prairie Provinces in the years 1961, 1962, and 1963, mail questionnaires were sent to every tenth farmer listed in directories published annually by the Canada Post Office Department. The questionnaires were mailed in October and follow-up questionnaires to non-respondents were mailed in November. In the 3 years, 59,240 questionnaires were sent and 19,071 usable replies were received (Table 2). Farmers were asked to state the location and amount of damage (in bushels) attributed to ducks, deer, cranes, and other wildlife. Values assigned for conversion of bushels to dollars were as follows: one dollar per bushel for wheat, 75 cents per bushel for barley and rye, 50 cents per bushel for oats, and two dollars per bushel for flax and rape.

Locations of farms of respondents attributing damage to sandhill cranes indicate damage was scattered in a broad band across the grain-growing

TABLE 2 Prairie wildlife damage questionnaire mailings and responses

Year	Questionnaires mailed	Undelivered	Total responses	Usable responses
1961	20,717	180	9,684	8,255
1962	19,221	162	6,332	4,812
1963	19,302	348	6,812	6,004
Pooled	59,240	690	22,828	19,071

Figure 6 Locations of farms on which indemnities for damage by sandhill cranes were paid in 1956–60.



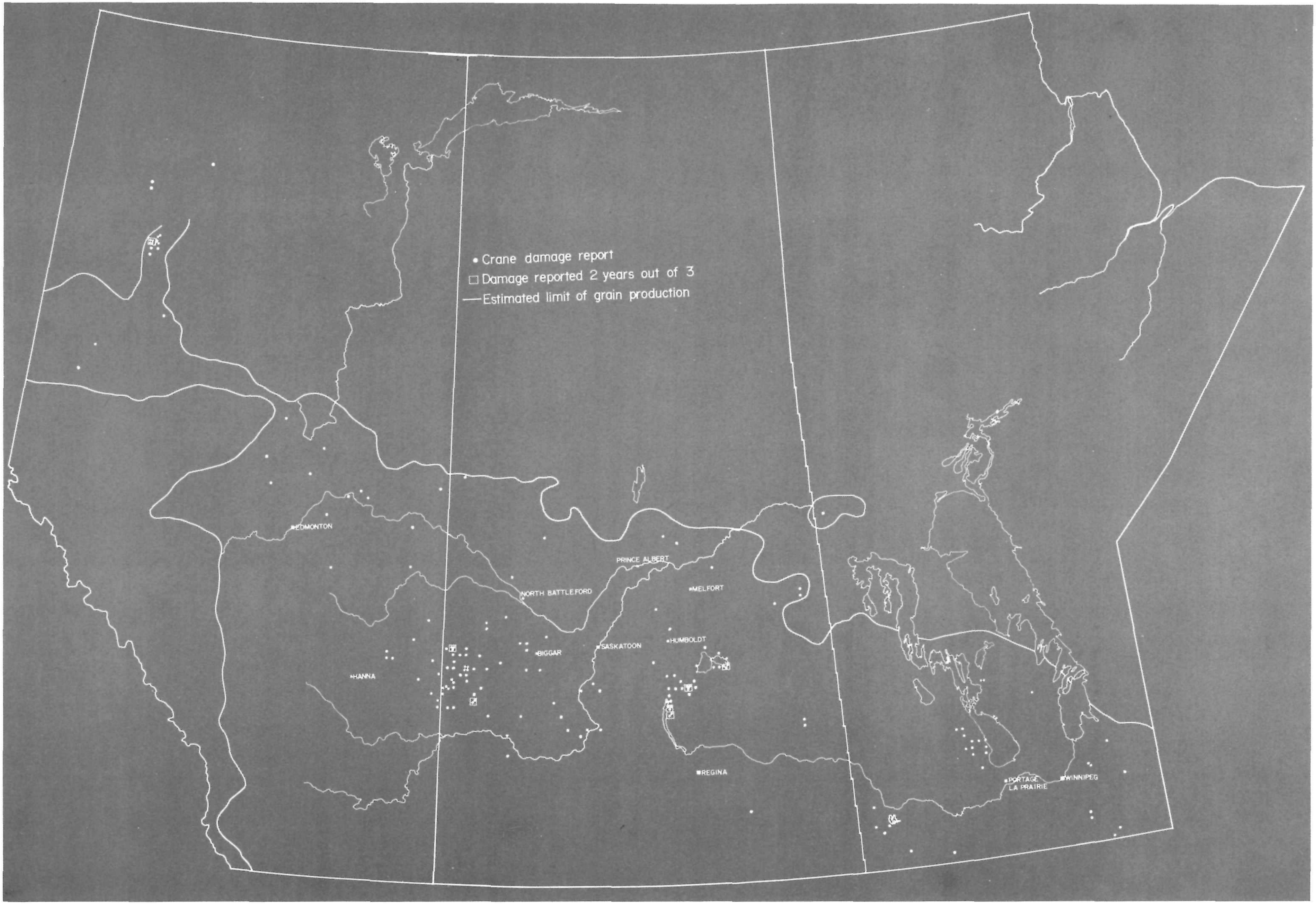


Figure 7 Locations of farms of respondents to mail questionnaires attributing damage to sandhill cranes 1961–63.

portion of the Canadian Prairies, from southeastern Manitoba to northwestern Alberta (Fig. 7). Damage was most frequent in the vicinity of the north end of Last Mountain Lake and Quill Lakes, Saskatchewan. Reports from the vicinity of Big Grass Marsh, west of Lake Manitoba, and from west-central Saskatchewan and east-central Alberta suggest that a number of farms are affected there but not as frequently and the affected farms are widely dispersed. Table 3 indicates that the annual mean value of damage attributed to cranes was $184.41 per damaged farm. Total damage estimated by farmers was $25,817.75.

TABLE 3 Value of damage by sandhill cranes to grain crops in Prairie Provinces

Year	Number of respondents	Number reporting crane damage	Total value reported damage, $	Mean value reported damage, $
1961	8,255	33	1,874.75	81.51*
1962	4,812	62	13,456.25	236.07*
1963	6,004	73	10,486.75	174.78*
Pooled	19,071	168	25,817.75	184.41*

*Respondents reporting unspecified amounts of damage were excluded from calculation of mean.

The significance of the problem of damage to grain crops by cranes is its perennial occurrence in localized areas. Relatively few farmers are affected, although intolerable amounts of damage are borne by some individuals. The observed distribution of damage probably reflects the autumn distribution of crane populations.

Sandhill crane populations

Subspecific status

Farmers are inclined to regard sandhill cranes as another pest to be shot or poisoned. If hunting were to be resumed it would likely take place near the Last Mountain Lake Bird Sanctuary because of damage there. The Last Mountain Lake Bird Sanctuary, the first sanctuary established in North America by national legislation, is traditionally used by sandhill cranes and was reported to be used by the rare greater sandhill crane (Walkinshaw, 1960a, 1961).

Management of sandhill cranes was limited by the presumed occurrence of a rare subspecies, the greater sandhill crane. Accordingly, it was necessary as a preliminary part of this study to investigate the taxonomic status of sandhill cranes at Last Mountain Lake in particular, where the most severe crane damage occurs.

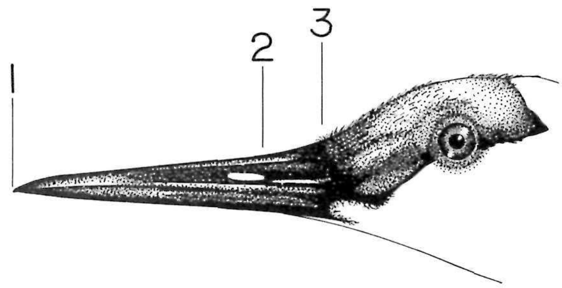


Figure 8 Head of sandhill crane illustrating measurement of culmen and exposed culmen.

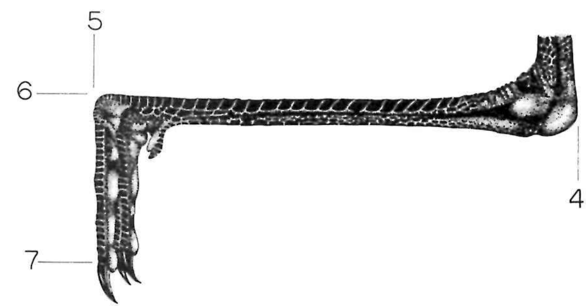


Figure 9 Tarsus and foot of *sandhill crane illustrating* measurement of tarsus and mid-toe.

To determine the subspecific affinities of sandhill cranes migrating through the Last Mountain Lake area 303 specimens were collected during the spring and autumn migrations of 1961, 1962, and 1963. Samples were taken by non-selective shooting from flocks passing between feeding and roosting areas. Birds were classed as adult if the loral and orbital regions were bare and red, and if the nape was grey. All others were classed as juveniles (Walkinshaw, 1949). Sex of specimens was determined from examination of the gonads as there was no known sexual dimorphism. Each specimen was weighed to the nearest 10 grams on a spring scale. Calipers were used to measure in millimetres the bill, the bill from tip to posterior nares, the tarsus, and the mid-toe. Total length was measured to the nearest centimetre.

As shown in Figure 8 the bill was measured from the tip (1) to the posterior edge of the nostril (2). The bill was also measured from the tip to the point where the dermis and culmen meet on adults (3) or where the feathers impinge on the culmen of juveniles. The tarsus was measured from the posterior edge of the tibio-tarsus joint (4) to the anterior edge of the tarsal-metatarsal joint (5) (Fig. 9). The mid-toe was measured from the anterior edge of the tarsal-metatarsal joint (6) to the last scute on the toe (7). The total length was measured from the tip of the bill to the longest rectrix with the bird gently stretched on a measuring board. Colour of shaft, and wear at the outer edge of the vane of the primary feathers, were also recorded.

Following Peters' (1934) check-list of birds of the world, Walkinshaw (1949) distinguished four subspecies of sandhill cranes on the basis of colour of the shafts of primary feathers, shade of colour of feathers on the hind neck and occiput, length of tarsus, and length of exposed culmen.[1] Shade of colour of feathers on hind neck and occiput was used only to distinguish the greater sandhill crane from the Florida sandhill crane resident in the southeastern United States. Walkinshaw (1965) has described a new subspecies, the Canada sandhill crane (*G. c. rowani*), on the basis of colour of shafts of primary feathers and of measurements of wing chord, bare tibia, tarsus, exposed culmen (*sic*), and bill from tip to posterior of nostril. Colour of hind neck and occiput was not considered important in Saskatchewan cranes, and measurements of bare tibia and wing chord were considered to lack consistency. Data on the other four characters as exhibited by Last Mountain Lake specimens were analysed.

Dark grey primary shafts are characteristic of the subspecies *canadensis*, and whitish or yellowish shafts typical of *tabida* (Walkinshaw, 1949). The primary feather shafts of *rowani* are lighter than those of *canadensis* (Walkinshaw, 1965).

The shaft colour was examined in 127 specimens from Last Mountain Lake. Seven per cent had dark grey shafts on all primary feathers, 51 per cent had whitish or yellowish shafts on all primaries, and 42 per cent had shafts of both colours. Seventy per cent of the primary feathers with whitish or yellowish shafts showed evidence of wear at the tip of the vane while only 33 per cent of those with dark grey shafts were worn. The apparent relationship between wear at the tip of the feather and colour of the shaft, and the inconsistency of shaft colour on individual birds suggest that primary shaft colour is not a reliable taxonomic characteristic.

Walkinshaw (1949) did not discriminate between ages and sexes of cranes in his key to the subspecies and gave only overlapping ranges for comparison of measurements in the key and in his description of the new subspecies *G. c. rowani* (Walkinshaw, 1965). The approach to identification of subspecies at Last Mountain Lake was limited to examining frequency polygons of the measurements of diagnostic characters to determine the probable proportions of each subspecies present.

The mean, standard deviation, and ranges of weight and measurements of tarsus, bill (exposed culmen), bill from tip to posterior of nostril, mid-toe, and total length of adult sandhill cranes collected at Last Mountain Lake are shown in Table 4. The frequency polygons for weight (d^2=.0553), length of tarsus (d=.0741), bill

[1] Exposed culmen is not a common ornithological term. Walkinshaw (1949) did not describe his measurements but his data on exposed culmen and tarsus length are presumed to be comparable to bill and tarsus measurements taken in this study.

[2] The "d" value is the measure of "goodness of fit" to an expected distribution calculated using the Kalmogorov-Smirnov test (Massey, 1951).

Figure 10 Frequency polygon and expected normal distribution of weights of adult male sandhill cranes from Last Mountain Lake, Saskatchewan.

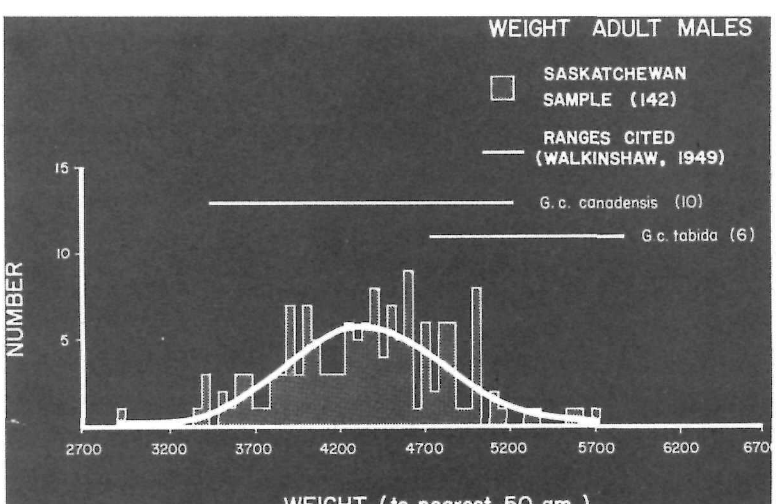


Figure 11 Frequency polygon and expected normal distribution of length of bill of adult male sandhill cranes from Last Mountain Lake, Saskatchewan, compared to type males and ranges of the subspecies *G. c. canadensis*, *G. c. rowani*, and *G. c. tabida*.

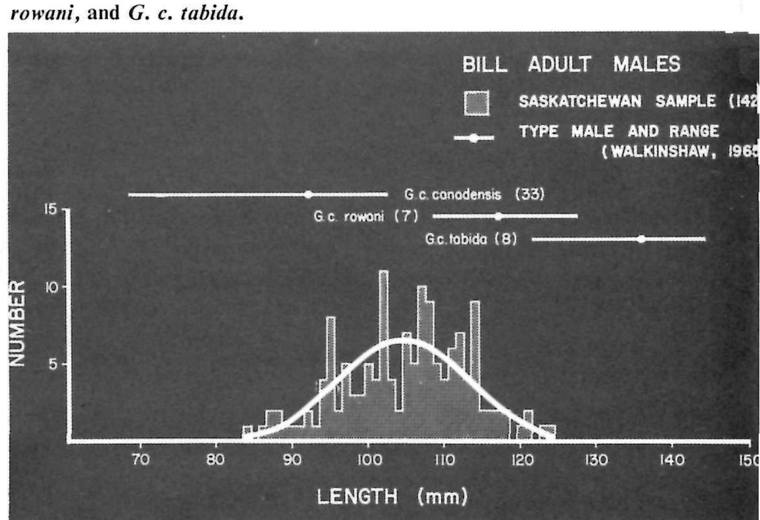


TABLE 4 Weights and measurements of adult sandhill cranes at Last Mountain Lake, Saskatchewan

	Weight, gm.	Total bill, mm.	Bill from tip to posterior nares, mm.	Tarsus, mm.	Midtoe, mm.	Total length, mm.
Males:						
Lowest	2950	84	67	184	70	880
Mean	4376.1	104.6	82.6	232.5	81.3	995.5
Highest	5730	124	102	266	93	1150
Standard deviation	492.3	8.5	6.5	17.7	4.9	46.0
Critical "d" value*	.1141	.1141	.1373	.1149	—†	—
Sample size	142	142	98	140	128	130
Females:						
Lowest	2810	82	65	170	67	860
Mean	3853.3	97.9	77.1	216.2	76.9	940.6
Highest	5000	121	95	251	90	1070
Standard deviation	592.5	12.4	6.1	27.8	8.9	46.8
Critical "d" value	—	—	—	—	—	—
Sample size	113	111	82	110	105	95

*Kolmogorov-Smirnov test.
†—indicates not tested.

(d = .0416), and bill from tip to posterior of nostril (d = .0904) of adult males conformed to the normal distribution expected with each mean and standard deviation (Table 4 and Figs. 10, 11, 12, and 13).

The range of measurements given for *G. c. canadensis* males (Walkinshaw, 1965) overlaps the distribution of measurements of Last Mountain Lake specimens by 38.2 per cent in length of bill (Fig. 11), 15.4 per cent in length of bill from tip to posterior of nostril (Fig. 12), and 10.6 per cent in length of tarsus (Fig. 13). The range of measurements given for *G. c. rowani* males (Walkinshaw, 1965) overlaps the distribution of measurements of Last Mountain Lake specimens by 29.5 per cent in length of bill (Fig. 11). *G. c. rowani* males occupy only 33.3 per cent and 46.8 per cent of the distribution of measurements of bill from tip to posterior of nostril (Fig. 12) and tarsus (Fig. 13) of the Last Mountain Lake specimens. The range of measurements given for *G. c. tabida* males (Walkinshaw, 1965) overlaps the distribution of measurements of Last Mountain Lake specimens by 2.0 per cent in length of bill (Fig. 11), 0.2 per cent in length of bill from tip to posterior of nostril (Fig. 12), and 64.4 per cent in length of tarsus (Fig. 13). Extremes of measurements of 46 adult male sandhill cranes taken in New Mexico (Boeker *et al.*, 1961) overlapped the measurements of Last Mountain Lake specimens by 75.2 per cent in length of bill from tip to posterior of the nostril (Fig. 12), 17.6 per cent in length of tarsus (Fig. 13), and 20.3 per cent in weight (Fig. 10). It is concluded

Figure 12 Frequency polygon and expected normal distribution of length of bill from tip to posterior of nostril of adult male sandhill cranes from Last Mountain Lake, Saskatchewan, compared to type males and ranges of the subspecies *G. c. canadensis*, *G. c. rowani*, and *G. c. tabida*.

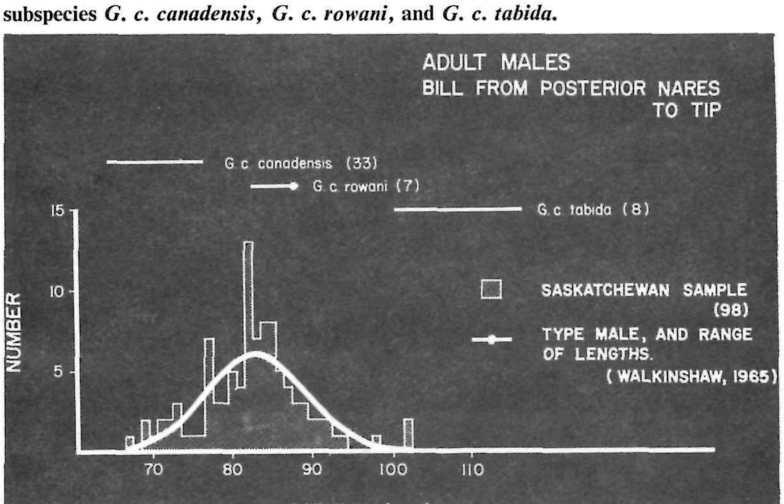
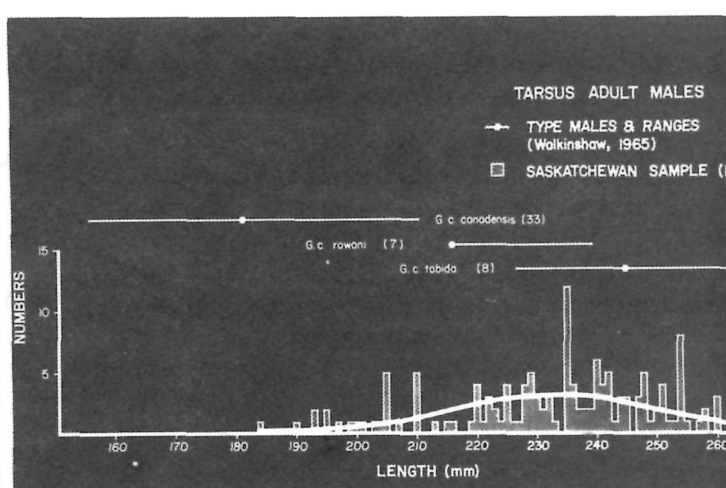


Figure 13 Frequency polygon and expected normal distribution of length of tarsus of adult male sandhill cranes from Last Mountain Lake, Saskatchewan, compared to type and ranges of *G. c. canadensis*, *G. c. rowani*, and *G. c. tabida*.



that attempts to differentiate subspecies by the criteria used are not warranted for the following reasons: the colour of shafts of primary feathers is not a reliable taxonomic character; at least 75 per cent of the Last Mountain Lake sandhill crane specimens could not be assigned to one subspecies (Mayr *et al.*, 1953); the measurements of adult males follow a normal distribution indicating a single population; there is a lack of correlation of diagnostic characters; and New Mexico sandhill crane specimens show considerable overlap.

TABLE 5 Estimates of sandhill crane populations at Last Mountain Lake, 1947, 1952, and 1960

Date	1947*	1952†	1960‡
August 12			300
August 14	150		
August 16	1,300		1,000
August 19		7,000	
August 25			5,000
August 27	10,000–12,000		
September 2			15,000
September 10		Peak population attained	
September 13	4,000		
September 14	6,240		
September 15			25,000
September 20			25,000+
September 27			14,000
September 30		Population declined	
October 5			13,000
October 12			5,000
October 23			1,000

*Estimates attributable to Munro (1950).
†Estimates attributable to Sterling (pers. comm.).
‡Estimates attributable to Gollop (pers. comm.).

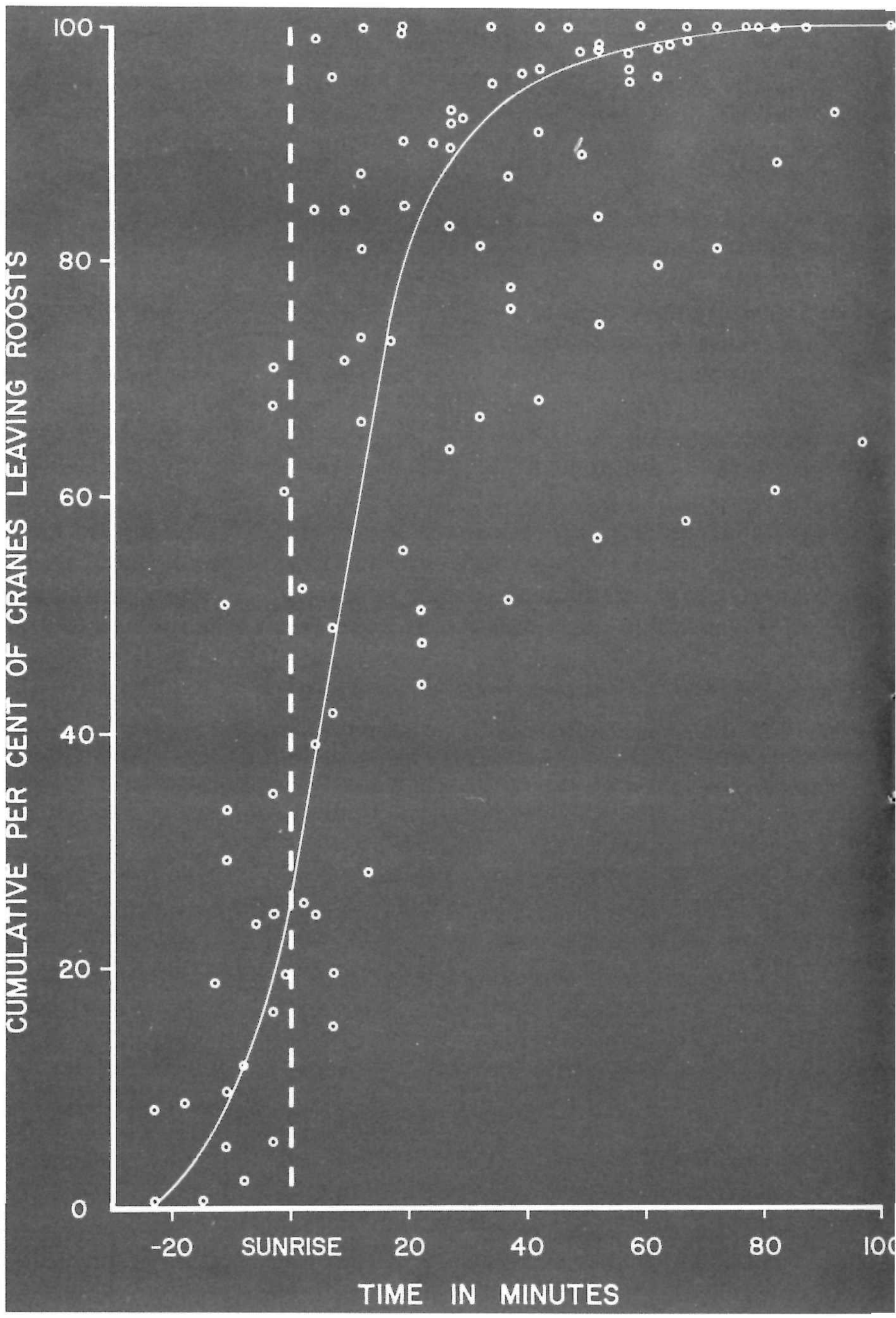
Accordingly, management of migrant sandhill cranes in western Canada need not be restricted. It should be based on the preservation of local nesting populations where that is desirable and on sound demographic data for the total population.

Population numbers

Estimates of the crane populations at Last Mountain Lake were made in 1947 (Munro, 1950), 1952 (Sterling, pers. comm.), and 1960 (Gollop, pers. comm.) as shown in Table 5. None of these estimates is referable to the exact area used for this study or the entire autumn migration period but they provide some information on the pattern of change in population size. Munro (1950) estimated that in 1947 the sandhill crane population at Last Mountain Lake reached a seasonal peak of 10,000 to 12,000 during the last week of August. Sterling estimated there were at least 7,000 cranes around the north end of Last Mountain Lake on August 19, 1952, but stated that peak populations were not present until September 10 and "there was little reduction between this date [September 10] and the end of the month". Gollop estimated peak populations of more than 25,000 cranes at the north end of Last Mountain Lake on September 20, 1960.

The sandhill crane populations of interest during this study were those present during the late summer and early autumn, the period that ripened

Figure 14 Estimated percentage of cranes leaving roosts in relation to sunrise.



unthreshed grain crops are susceptible to damage. A few cranes were observed at the north end of Last Mountain Lake during July of 1961 and 1962, and as many as 300 were observed in July 1963, but because their numbers were relatively few, and because little damage is caused until grain ripens in early August, they were not important to this study.

Specific techniques for censusing sandhill cranes had not been previously developed or studied, and so little was known of their group behaviour or feeding patterns that there was no basis for applying conventional sample-count methods. Reports that cranes concentrate on night roosts, that night roosts are used more consistently than day roosts, and that most cranes do not leave night roosts until sunrise (Munro, 1950; Walkinshaw, 1949) suggested that total counts of cranes on or leaving their night roosts might be feasible and might be the most accurate census possible.

Counts were made at weekly intervals during 1961 by observers located at strategic points (Fig. 3) from which they could see cranes leaving night roosts. On the mornings of August 18, 25, and 30, 1961, beginning one-half hour before sunrise, cranes leaving the roosts were counted and the time of day noted. Observers generally remained one-half hour after the last crane was observed leaving. To avoid duplication only one observer recorded cranes passing over each segment of the lakeshore.

The counts made in 1961 are shown in Table 6. Cranes began to leave night roosts about 23 minutes before sunrise, and an estimated average of at least 25 per cent of the cranes had left the roosts by sunrise (Fig. 14). In 1962 and 1963 the counts of cranes were made from an aircraft. Census flights began one-half hour before sunrise but were not completed until sunrise. A measure of the bias in the population estimates for 1962 and 1963 due to cranes missed was derived from comparison of the rate of completion of the census with an estimated average rate of cranes leaving roosts based on the observations made in 1961.

TABLE 6 Observed and indicated sandhill crane populations roosting within the Last Mountain Lake study area in 1961, 1962, and 1963

Date	1961	1962		1963		3-point average
		Observed	Indicated	Observed	Indicated	
Aug. 7				1,061	1,517	
8		350	500			
14				10,601	15,159	11,650
15		1,712	2,448			
18	7,514					
21				12,779	18,274	15,630
22		3,715	7,576			
25	12,803					
28				9,411	13,458	15,971
30	11,437	9,132	13,059			
Sept. 3		9,949	14,227			
4				11,315	16,180	15,635
5		8,293	11,856			
10		7,904	11,302			
12				12,075	17,267	16,722
13		4,775	6,828			
18				11,691	16,718	14,573
20		10,187	14,567			
25				6,810	9,738	12,353
26		9,345	13,363			
Oct. 2				7,415	10,603	10,906
3		6,880	9,838			
9				8,655	12,377	7,985
10		6,239	8,922			
16				681	974	7,410
17		0	0			
25				6,210	8,880	4,609
30				2,750	3,932	

If the rate of completion of the census and the rate of departure of cranes from the roosts are assumed to be linear (Fig. 15), the lines describing those rates and the co-ordinate axes will form areas which are proportional to the cumulative number of cranes observed and the cumulative number of cranes missed. For example, on the average no cranes would be missed on roosts counted up to 23 minutes before sunrise, but on roosts censused subsequently some percentage of the cranes would have already departed, until on the last roost counted, at sunrise, an average of 25 per cent of the cranes on that roost would have left without being counted. Thus it was estimated that the cranes observed averaged 80.2 per cent of the cranes present and a factor of 1.24 (= 100.0/80.2) was used to correct the observed counts in 1962 and 1963.

The census flights were carried out at an altitude of 300 feet and an airspeed of 85 miles per hour. Observations were made by the pilot, who recorded the numbers of cranes and their locations with a tape recorder for later transcription. The pilot was supplied with a map showing the census route and the direction to be followed (Figs. 4 and 5), as well as eight reference photographs of wheat kernels representing crane concentrations (Fig. 16).

The reference photographs were selected from a set of 21 prepared by distributing known numbers of wheat kernels over brown backgrounds so that they resembled crane concentrations on roosts as seen from an aircraft flying at an altitude of 300 feet. The full set of 21 contained distributions of 50, 100, 250, 500, 750, 1000, and 1500 kernels. A measure of the ability of the pilot-observer to estimate crane numbers was obtained by recording his estimate of the numbers of wheat kernels appearing in each photograph when allowed to view it for 10 seconds. The first test was given to the pilot-observer after a trial census flight on July 29, 1962, and the test was repeated on three other occasions at intervals of a week to 10 days. The photographs were displayed in random order each time and on the last test eight photographs were omitted.

During the 76 tests with photographs the observer estimated a total of 38,955 when there were actually 44,700 kernels. The observations of cranes recorded were therefore adjusted by a factor of 1.15 (=44,700/38,955) to correct for estimation bias. Observations of cranes recorded in aerial census of roosts in 1962 and 1963 were adjusted by a factor of 1.43 (=1.24 x 1.15) because of the effect of omission and estimation biases. This correction factor is merely an acknowledgement that census techniques were imperfect. As well as a comparable trend in numbers an estimate of the absolute number of cranes present was necessary for this study.

The observed counts of sandhill cranes roosting on Last Mountain Lake and corrected estimates of the population sizes are shown in Table 6. The numbers of cranes increased rapidly beginning the first week of August. Populations peaked at 18,000 in the third week of August, remained high until the second week of September, and then declined until the last cranes left after the middle of October. This pattern for Last Mountain Lake is consistent with that reported by Munro (1950), Sterlins (pers. comm.), and Gollop (pers. comm.). In other areas of western Canada where damage by cranes is

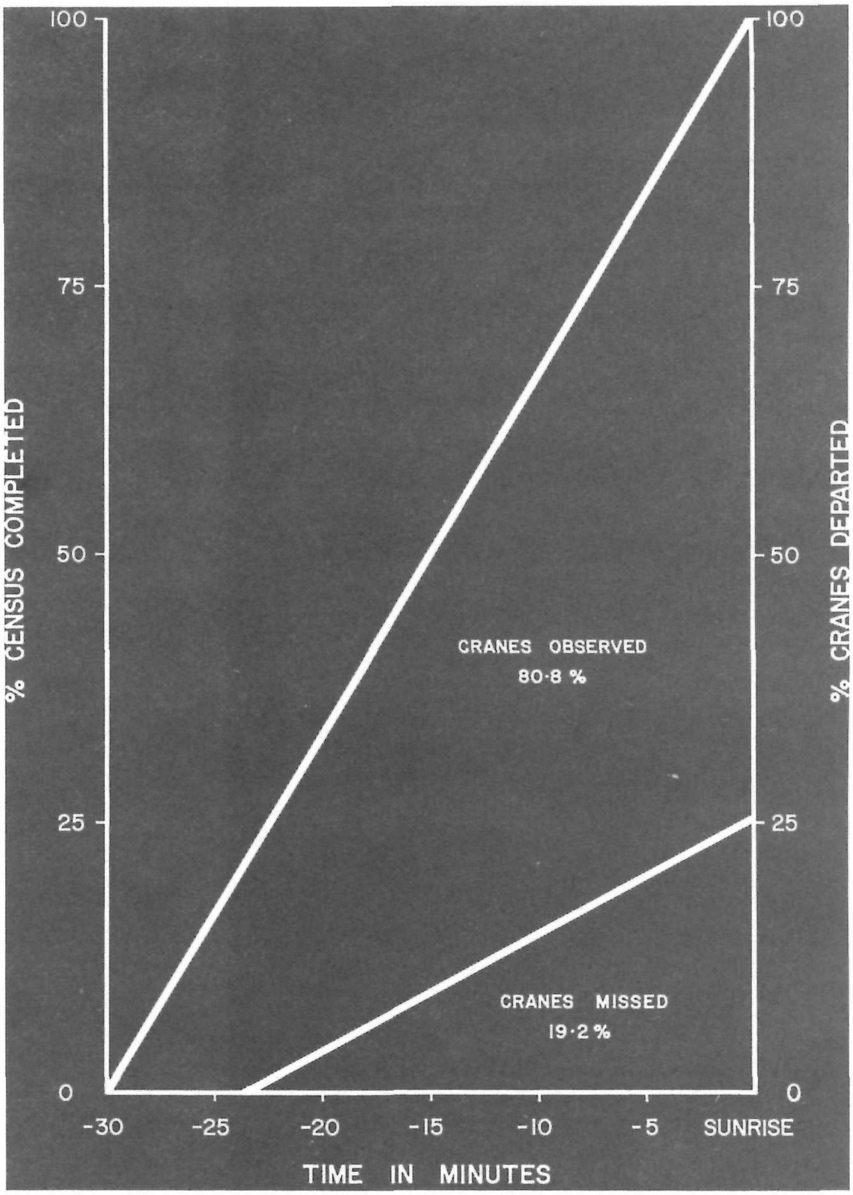
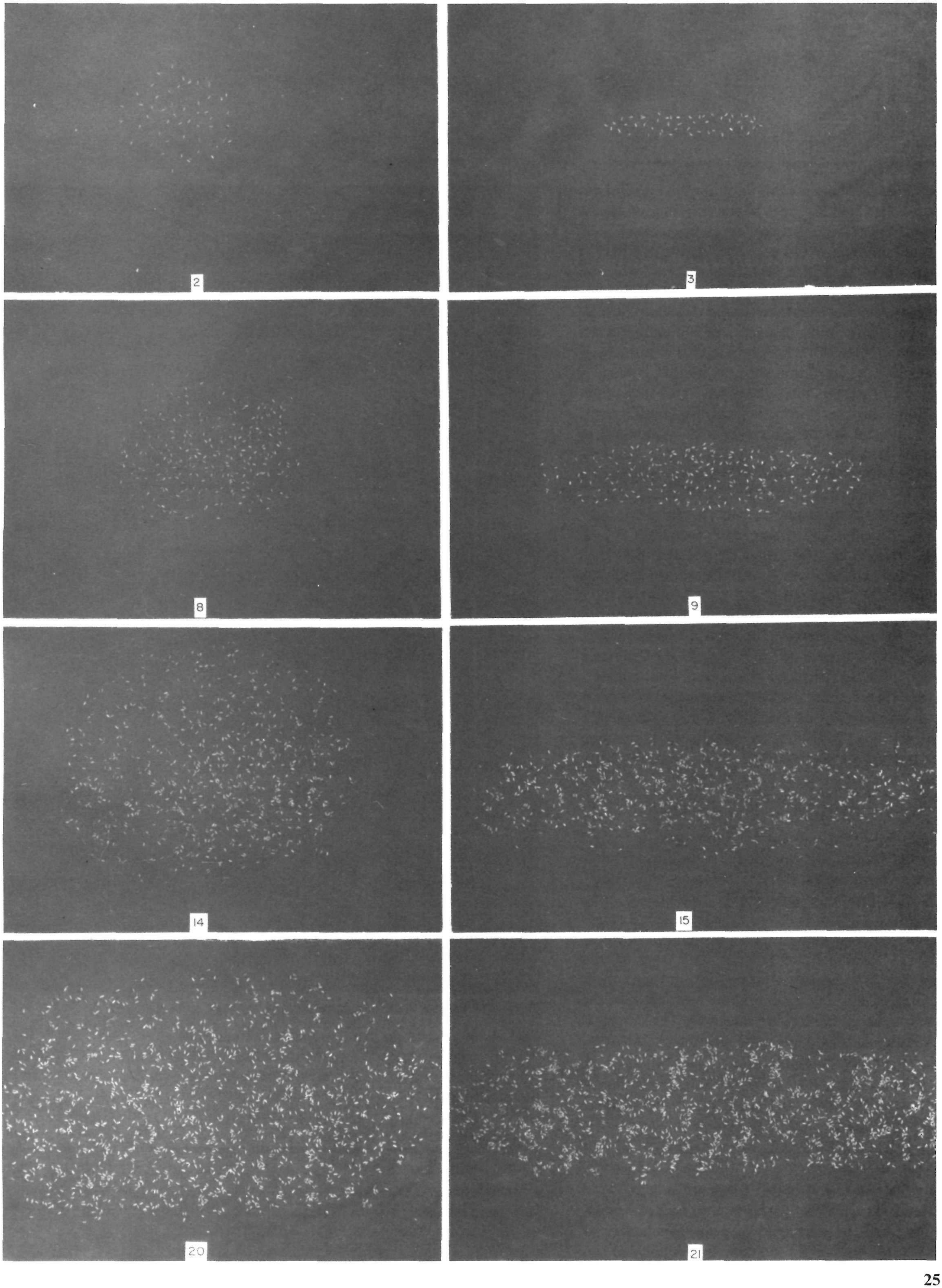


Figure 15 Rate of completion of census and rate of departure from roosts.

Figure 16 Photographs used as reference in estimation of numbers of sandhill cranes, showing distribution of 50 (2 and 3), 250 (8 and 9), 750 (14 and 15), and 1500 (20 and 21).


2
3
8
9
14
15
20
21

reported there are notable variations in crane population size and progress of autumn migration. At Big Grass Marsh, Manitoba, peak numbers of 6,000 cranes are reported to occur during the first part of August (W. R. Miller, pers. comm.). In west-central Saskatchewan peak numbers of 50,000 cranes are reported in some locations along the South Saskatchewan River but not until late September, when the grain harvest is usually completed. Those observations suggest that susceptibility to damage is related to accumulated time spent by a crane population in an area during the period that grain crops are ripe and unthreshed rather than to numbers of cranes alone.

The accumulated time that a crane population spends in an area can be measured as crane-days, defined as the foraging activity of one crane for 1 day. The cumulative number of crane-days at Last Mountain Lake was calculated from the 1963 population estimates. As will be shown later the numbers of cranes roosting at Last Mountain Lake in 1961 and 1962 were affected by experimental treatments and therefore did not provide a reasonable basis for estimation. Although the estimated population was assumed to represent total numbers of cranes present at the time of census, a three-point moving average was used (Fig. 17) to estimate the populations present between counts. Data on grain harvesting for comparison with the cumulative number of crane-days (Table 7) were obtained from the Statistics Division of the Saskatchewan Department of Agriculture.

Records of annual harvesting progress for wheat are maintained and categorized as follows: (1) date cutting commenced, (2) date threshing commenced, (3) date threshing general, (4) date cutting completed, and (5) date threshing completed. Records of the date threshing was completed are not continuous because in some years with poor harvest weather threshing is completed the following spring, if at all. Threshing general is the term used for the stage when all farmers are threshing. These records are compiled for each crop district or statistical subdivision of the province.

In an average year most farmers near Last Mountain Lake are threshing their crops by September 1 (Table 7), and by extrapolation an estimated 350,000 crane-days occurred before then in 1963, which was considered an average year in terms of cranes and crops. As only unthreshed crops are susceptible to damage, the problem with cranes at Last Mountain Lake might be attributed to peak populations of 18,000 cranes, or to 350,000 accumulated crane-

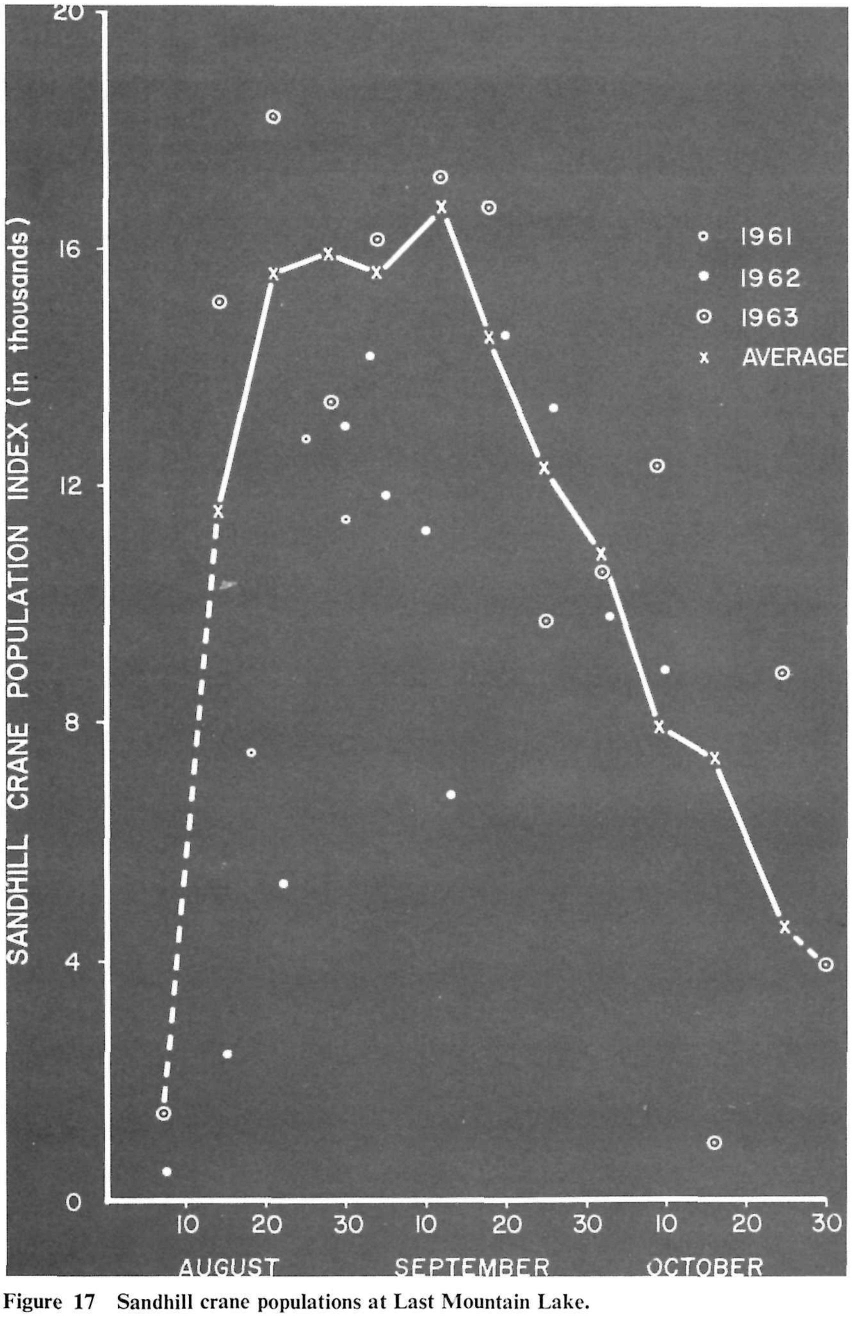


Figure 17 Sandhill crane populations at Last Mountain Lake.

days. Similar data on crane populations and harvesting progress, using the methods outlined in this study, should be collected for other areas in western Canada to estimate the comparative susceptibility to crane damage, and then used to design application of treatments for its control.

Experimental treatments

Treatments of grain fields

Acetylene exploders will prevent ducks from landing in grain crops (Stephen, 1961), and although it seemed likely that exploders could also be used to

TABLE 7 Estimated cumulative number of crane-days at Last Mountain Lake related to harvesting progress

Date		Threshing commenced		Threshing general		Cumulative number of cranes, 1963
		Years	Cumulative per cent	Years	Cumulative per cent	
August	12	1	3.8	0	0	26,200
	17	0	0	1	3.8	113,400
	18	1	7.6	0	0	127,200
	20	2	15.3	0	0	156,600
	21	1	19.1	0	0	172,200
	22	3	30.6	0	0	187,800
	23	2	38.3	0	0	203,400
	24	2	46.0	0	0	219,000
	25	2	53.7	0	0	234,800
	26	4	69.1	1	7.6	250,600
	27	0	0	1	11.4	266,400
	28	1	72.9	0	0	282,400
	29	1	76.7	2	19.1	298,200
	30	0	0	5	38.3	314,000
	31	0	0	2	46.0	329,800
September	1	3	88.2	0	0	345,400
	2	0	0	2	53.7	361,000
	3	0	0	1	57.5	376,600
	4	0	0	1	61.3	392,200
	6	0	0	2	69.0	423,600
	7	0	0	1	72.8	439,600
	8	0	0	1	76.6	455,600
	9	1	92.0	2	84.3	471,800
	10	1	95.8	0	0	488,200
	11	0	0	0	0	504,600
	12	1	99.6	1	88.1	521,200
After September	12	0	0	3	99.6	967,400
Total		26		26		

scare cranes, there was no knowledge of the method or rate of application required. Exploders were applied to unharvested grain crops only after cranes had been reported in them by farmers or by the technicians who patrolled the study area. It is generally considered more difficult to prevent cranes from landing in a field once they have begun to use it regularly; but the procedure of treating crops after susceptibility to damage was verified assured that the minimum number of exploders would be used and that the effects of displacement of cranes from one field to another would be most clearly shown.

In 1961, exploders were installed as needed throughout the study area, but in 1962 and 1963 only grain crops in the western two-thirds (Ranges 23 and 24) were treated. The treated and untreated blocks in 1962 and 1963 were compared for the effects of treatments. The number, range of dates, and total duration of treatments are shown in Table 8. Dates of application and duration in each

TABLE 8 Treatments of commercial grain crops with acetylene exploders

Year	Number quarter sections treated	Total number treatment days	First exploder installed	Treatment evaluation		Last exploder removed
				Dates	Days	
1961	35	216	Aug. 12	Aug. 15–30	16	Sept. 11
1962	58	1,370	Aug. 1	Aug. 15 to Sept. 12	29	Sept. 25
1963	19	214.5	Aug. 10	Aug. 10 to Sept. 15	37	Sept. 8
Pooled	112	1,800.5			82	

quarter section in each year are shown in Table 9.

In the total sample of 112 treatments, exploders operated for periods ranging from 0.5 days to 54.5 days with a mean of 16.0±1.17 (SE) days. In 1961, the 35 treatments ranged from 0.5 to 26.5 days with a mean of 6.0±0.90 (SE) days; in 1962, the 58 treatments ranged from 2.5 to 54.5 days with a mean of 23.5±1.56 (SE) days; and in 1963 the 19 treatments ranged from 1.0 to 22.0 days with a mean of 11.0± 1.49 (SE) days. Treatment periods were calculated to the nearest half day. Fields in which exploders were installed during the 4 hours following sunrise or preceding sunset were not considered treated until the beginning of the following half day, and fields from which exploders were removed in the 4 hours following sunrise or preceding sunset were considered treated only up to the end of the preceding half day.

Locations of exploders in each quarter section are shown in Figures 3, 4, and 5. The 112 treatments were in 95 different quarter sections. One quarter section was treated each of the 3 years; 14 in 2 years; and 81 in only 1 year.

TABLE 9 Date of application and duration of treatments in the Last Mountain Lake study area

Location	1961		1962		1963	
	Application date	Duration	Application date	Duration	Application date	Duration
SE 5-27-23	Aug. 25	6.5	—	—	—	—
NW 5-27-23	Aug. 16	5	—	—	—	—
NW 6-27-23	—	—	Sept. 6	6.5	—	—
NE 8-27-23	Aug. 23	13	—	—	—	—
SE 8-27-23	—	—	Sept. 2	10.5	Aug. 12	1
SW 8-27-23	Aug. 19	2	—	—	—	—
NW 8-27-23	Aug. 16	2.5	—	—	—	—
SE 9-27-23	—	—	Aug. 25	25	—	—
SW 9-27-23	—	—	—	—	Aug. 24	9
NW 14-27-23	—	—	Aug. 24	32	—	—
NE 15-27-23	—	—	—	—	Aug. 27	8
SW 15-27-23	—	—	Sept. 4	15.5	—	—
NW 15-27-23	—	—	Aug. 16	8	—	—
NE 20-27-23	—	—	Aug. 14	11.5	—	—
SE 21-27-23	Aug. 20	6	Aug. 25	26	—	—
SW 3-28-23	—	—	—	—	Aug. 13	22
SW 4-28-23	Aug. 16	1	—	—	Aug. 13	5.5
NW 4-28-23	Aug. 23	1	—	—	—	—
SW 5-28-23	Aug. 16	.5	—	—	—	—
NE 5-28-23	—	—	Sept. 5	11	—	—
SE 9-28-23	Aug. 25	6.5	—	—	—	—
SE 13-28-23	Aug. 18	9	—	—	—	—
NE 15-28-23	—	—	—	—	Aug. 14	22
SW 16-28-23	Aug. 19	5	Aug. 16	26.5	—	—
SE 21-28-23	Aug. 17	10.5	—	—	—	—
NW 26-28-23	—	—	Aug. 22	32	—	—
NE 28-28-23	Aug. 18	7	—	—	—	—
NW 30-28-23	Aug. 13	8.5	Aug. 1	53.5	—	—
NE 31-28-23	—	—	Aug. 7	35	—	—

TABLE 9 *continued*

Location	1961 Application date	1961 Duration	1962 Application date	1962 Duration	1963 Application date	1963 Duration
SE 31-28-23	—	—	Aug. 1	54.5	—	—
SW 31-28-23	Aug. 15	1.5	Aug. 1	53.5	—	—
SE 32-28-23	Aug. 17	15.5	—	—	—	—
SW 35-28-23	Aug. 23	2	—	—	—	—
NW 35-28-23	—	—	Aug. 14	33	Aug. 21	3
NW 3-27-24	—	—	Aug. 25	23.5	—	—
NE 4-27-24	—	—	Aug. 25	26.5	—	—
NE 5-27-24	—	—	Aug. 26	23	—	—
NW 10-27-24	Aug. 24	2	—	—	—	—
NE 15-27-24	—	—	Aug. 22	27.5	—	—
SE 15-27-24	—	—	Aug. 22	27.5	—	—
NW 15-27-24	—	—	Aug. 14	8	Aug. 25	12
SW 16-27-24	—	—	Aug. 17	32	—	—
NW 16-27-24	—	—	Aug. 17	38.5	—	—
SE 17-27-24	—	—	Aug. 26	24	—	—
SW 17-27-24	—	—	Aug. 26	24	—	—
SW 18-27-24	—	—	Aug. 31	22.5	Aug. 22	6
SW 20-27-24	—	—	Aug. 26	24	—	—
NE 22-27-24	—	—	Aug. 27	23.5	—	—
SE 22-27-24	—	—	Aug. 12	8	—	—
NW 22-27-24	—	—	Aug. 27	23.5	—	—
NW 26-27-24	Aug. 23	1	—	—	—	—
SE 28-27-24	—	—	Aug. 23	27.5	—	—
NE 28-27-24	—	—	Aug. 23	27.5	—	—
SW 1-28-24	—	—	Aug. 14	11	—	—
NW 1-28-24	—	—	Aug. 14	11	—	—
NE 2-28-24	—	—	Aug. 17	31	—	—
SE 2-28-24	Aug. 16	3.5	Aug. 18	30.5	—	—
SW 2-28-24	—	—	—	—	Aug. 19	11.5
SW 3-28-24	—	—	—	—	Sept. 2	6
NW 3-28-24	Aug. 23	3	Sept. 7	14.5	—	—
SE 4-28-24	—	—	Sept. 1	20	—	—
SW 9-28-24	—	—	Sept. 3	19.5	—	—
SW 11-28-24	—	—	—	—	Aug. 19	8.5
NW 11-28-24	—	—	—	—	Aug. 19	16
SW 12-28-24	Aug. 16	26.5	—	—	—	—
NW 13-28-24	—	—	Aug. 2	17.5	—	—
NE 14-28-24	Aug. 16	5.5	Aug. 19	28.5	Aug. 19	7
NE 15-28-24	—	—	Aug. 18	38	—	—
NW 15-28-24	Aug. 21	3	Sept. 18	2.5	—	—
NW 16-28-24	—	—	—	—	Aug. 23	13
NE 23-28-24	—	—	Sept. 5	19.5	—	—
NE 24-28-24	—	—	Aug. 19	10	—	—
SE 24-28-24	—	—	Aug. 19	10	—	—
SW 25-28-24	Aug. 24	6	—	—	—	—
NW 25-28-24	—	—	—	—	Aug. 10	8
NE 2-29-23	—	—	Aug. 14	35.5	—	—
NW 2-29-23	—	—	Aug. 14	32.5	—	—
NW 3-29-23	—	—	Aug. 20	5.5	—	—
SW 4-29-23	—	—	Aug. 9	11	—	—
NW 4-29-23	—	—	Aug. 20	34.5	—	—
NE 6-29-23	Aug. 16	1	—	—	—	—
SW 7-29-23	—	—	Aug. 7	7	Aug. 10	14
NW 7-29-23	—	—	Aug. 16	37.5	—	—
SW 9-29-23	—	—	Aug. 9	11	—	—
NE 11-29-23	Aug. 27	11.5	—	—	—	—
SE 12-29-23	Aug. 28	10.5	Aug. 22	33.5	—	—
SW 12-29-23	Aug. 15	8	—	—	—	—
NW 12-29-23	—	—	Aug. 20	30	—	—
NE 16-29-23	—	—	Aug. 25	22.5	—	—
SE 19-29-23	—	—	—	—	Aug. 13	20
SW 1-29-24	Aug. 27	3	—	—	—	—
SE 12-29-24	—	—	—	—	Aug. 12	22

TABLE 10 Numbers and frequency of occurrences of sandhill cranes on treated and untreated quarter sections

Year	Miles from major roosts	Treated: Number quarters	Treated: Pooled occurrences	Treated: Pooled number of cranes	Untreated*: Number quarters	Untreated*: Pooled occurrences	Untreated*: Pooled number of cranes
1961	1	13	11	1,209	64	430	105,943
	2	11	2	105	77	332	53,765
	3	3	1	25	63	272	37,804
	4	1	0	0	31	77	8,749
	>4	7	3	26	50	164	11,762
	Total	35	17	1,365	285	1,275	218,023
1962	1	21	7	340	42	186	43,806
	2	11	10	883	39	196	39,150
	3	16	11	1,387	43	132	17,721
	Total	48†	28	2,610	124	514	100,677
1963	1	3	2	272	40	383	97,609
	2	7	4	604	65	390	66,314
	3	5	4	120	45	235	36,143
	Total	15†	10	996	150	1,008	200,066
Pooled			55	4,971		2,797	518,766

*Includes cranes observed on quarter sections before and after treatment.
†Ten quarter sections in 1962 and four quarter sections in 1963 were treated but not evaluated.

Effectiveness of 98 treatments was evaluated by comparing the number and frequency of occurrence of cranes on treated and adjacent untreated quarter sections. An additional ten treatments in 1962 and four in 1963 were beyond the observer's patrols and are not included in the data in Table 10. The total sample of 4,971 cranes observed on 55 occasions during 98 treatments of 82 different quarter sections was compared with a total sample of 518,766 cranes observed on 2,797 occasions in 560 occupied untreated quarter sections. The differences between the mean number and mean frequency of occurrence of cranes occupying treated and untreated quarter sections (Table 11) were significant ($t_{.05}$). The average occupied untreated quarter section was used by 927 cranes while the average treated quarter section was used by 50 cranes.

As some cranes were obviously excluded from treated crops, the effects on crane foraging behaviour should be reflected in (1) use of alternative fields, (2) use of alternative roosts, or (3) departure of cranes from the study area. Although the most direct method of evaluating changes in crane behaviour was by following movements of distinct segments of the crane population, attempts to capture cranes for marking were unsuccessful, and segments of the natural populations could not be identified from day to day. Furthermore, lack of quantitative data on the normal distribution of cranes in grain fields prevented comparison with the response to treatments.

The first treatments each year were to crops located near roosts. As there was no general relationship apparent between completion of harvest and distance of crop from the roost and because treatments were applied only after cranes had been reported in the crops, displacement of cranes should be reflected by susceptibility of fields more remote from roosts. The distance relationship between crops and roosts was determined by circumscribing areas, using the locations of major roosts as the centres, and successive intervals of 1 mile as radii (Fig. 3). Quarter sections on the boundaries of the circumscribed areas were considered within the area closer to the roosts. As the mean date of application to quarter sections in the first mile was August 17, August 20 in the second mile, and August 23 in the third mile (Table 12), treatments caused displacement of sandhill cranes to alternative grain fields in the vicinity.

Although the mean date of treatment of crops more than 3 miles from major roosts on Last Mountain Lake was later than of those crops beside the lake, the progression was not consistent. However,

TABLE 11 Mean number and mean occurrence of cranes on treated and untreated quarter sections

Year	Treated		Untreated	
	Mean number cranes	Mean occurrence	Mean number cranes	Mean occurrence
1961	80.3	0.48	171.0	4.47
1962	93.2	0.58	195.8	4.14
1963	99.6	0.62	198.5	6.72
Pooled	90.4*	0.56†	185.5*	5.00†

*t=27.5 with 2 d.f.
†t= 5.9 with 2 d.f.

10 of the 19 treated quarter sections that were more than 3 miles from the lake roosts were also close to water areas known to be used by cranes, suggesting that exploder treatments caused use of alternative roosts as well as of alternative fields.

The population of cranes roosting on the shores of Last Mountain Lake decreased from an average of 10,585 in 1961 to 8,876 in 1962 (Table 6), suggesting use of other roosts. This decrease was associated with an increase in the number and duration of treatments (Table 8) and with a shift of distribution of cranes feeding in fields. In 1961 when fields were treated throughout the study area, 97 per cent (211,971 of 219,388) of the crane occurrences were in the western two-thirds of the study area (Ranges 23 and 24); but in 1962, when only grain fields in the western two-thirds were treated and when the number and duration of treatments increased, only 32 per cent (15,190 of 48,511) of the crane occurrences on aerial transects were in the western two-thirds of the study area (Table 13). However, the mean number of cranes observed on aerial transects in 1962 was 16,200 (Table 13), indicating no marked decrease in the number of cranes in the total study area compared to 1961.

Use of acetylene exploders will prevent sandhill cranes from landing in grain crops, but cranes will then forage in other fields in the vicinity. As the number and mean duration of exploder treatments increase, at least within the limits tested, the cranes will use alternative fields and roosts but will not leave the general area. The effects of exploder use are similar to those of shooting at cranes which drives them from one field to another (Munro, 1930), and if shooting were intensive, as in a hunting

TABLE 12 Mean dates of beginning of treatment in relation to distance from major roosts

		Distance from major roosts				
		First mile	Second mile	Third mile	Fourth mile	More than 4 miles
1961	Mean date	Aug. 17	Aug. 21	Aug. 21	Aug. 18	Aug. 20
	Sample size	13	11	3	2	5
1962	Mean date	Aug. 16	Aug. 20	Aug. 24	Aug. 23	Aug. 22
	Sample size	21	11	18	5	3
1963	Mean date	Aug. 17	Aug. 17	Aug. 18	Aug. 24	Aug. 13
	Sample size	4	7	5	3	1
	Pooled mean date	Aug. 17	Aug. 20	Aug. 23	Aug. 22	Aug. 20
	Sample size	38	29	26	10	9

TABLE 13 Distribution of foraging sandhill cranes in study area, 1962 and 1963

	Date	Total cranes	Range 22 cranes	Ranges 23 & 24 cranes
Peripheral roosts untreated 1962	September 3	11,140	8,121	3,019
	September 5	22,971	13,725	9,246
	September 10	14,400	11,475	2,925
	Pooled	48,511	33,321	15,190
Peripheral roosts treated 1963	August 7	330	300	30
	August 14	3,552	27	3,525
	August 21	4,777	136	4,641
	August 28	439	25	414
	September 4	1,447	999	1,348
	September 13*	1,841	661	1,180
	Pooled	13,286	2,148	11,138

*Roosts were treated only until September 8, but a crane census could not be made until September 13.

season on cranes for example, similar displacement to other roosts might be expected. Susceptibility to damage is transferred to other fields and other farms so that shooting or acetylene exploder treatments actually exposes a greater number of fields to damage.

Treatments of crane roosts

As displacement of cranes to other fields tends to expose more farmers to damage, a method of restricting the area occupied by cranes was needed. From observations during spring migrations and during the 1961 and 1962 experiments, it seemed that cranes tend to forage in fields closest to their roosts and, conversely, tend to roost on suitable water areas closest to fields in which they have been foraging. If this were correct, and there were only one suitable roost, all cranes would use suitable fields closest to that roost.

To restrict use of roosts by cranes, Gollop (pers. comm.) treated six small water areas with acetylene exploders in 1960. Only once during the treatments were more than 25 cranes observed, whereas previously groups of 50 to 400 were observed. It was apparent from Gollop's work that cranes might be displaced from roosts as well as grain fields, but there was no assessment of the changes in populations roosting elsewhere or occurrence of cranes in grain fields adjacent to the treated roosts.

The eight roosts in the northernmost 5 miles of Last Mountain Lake (Township 28) are close together, are separated from others by at least 3 miles, and may be considered a single roosting complex (Fig. 3). They were not treated. All other roosts in the study area were considered peripheral roosts and were treated in 1963. In all, 26 treatments were applied to roosts, 7 in bays on the southerly 6 miles of Last Mountain Lake within the study area (Township 27) and 19 on small water areas in uncultivated land north and east of the lake (Fig. 5). Roosts in the study area west of the lake were not used during autumn migration.

The mean number of cranes roosting on Last Mountain Lake during the period of peripheral roost treatment was 12,917 (Table 14), while during a comparable period in 1962 when roosts were not treated the mean number of cranes was 7,947. Only 14 per cent (9,326 of 64,588) of the pooled samples of cranes censused were on treated roosts compared with 53 per cent (22,312 of 47,683) on the same untreated roosts during a similar period in 1962. The increase in the number of cranes roosting on Last Mountain Lake was associated with a shift in the distribution of cranes foraging in fields. Thirty-two per cent (15,190 of 48,511) of the cranes noted during aerial transects were in grain fields in the western two-thirds of the study area in 1962, but 84 per cent (11,138 of 13,286) were in the same area when peripheral roosts were treated in 1963 (Table 13). An increase within the ground patrol area in the number of quarter sections occupied by cranes, from 124 in 1962 to 150 in 1963 (Table 10), was also associated with the treatments of peripheral roosts, although the mean number and the mean frequency of occurrence of cranes per quarter section did not change appreciably (Table 11). More of the quarter sections in the second mile from the major roosts were occupied in 1963 than in 1962, but the number of quarter sections occupied in the first mile and third mile from the roosts was about the same (Table 10). The proportion of treatments applied in quarter sections adjacent to the northern 5 miles of Last Mountain Lake (Townships 28 and 29) also increased from 57 per cent in 1962 to 74 per cent in 1963.

Acetylene exploders can be used to change the distribution of roosting cranes as shown on Last Mountain Lake in 1963, but the increase in the mean number of roosting cranes observed indicates that treatment of peripheral roosts does not cause

TABLE 14 Indicated crane populations on treated and untreated roosts at Last Mountain Lake in 1962 and 1963

	1962			1963	
Census date	Northern untreated	Southern untreated	Census date	Northern untreated	Southern treated
Aug. 8	59	442	Aug. 7	722	795
Aug. 15	921	1,805	Aug. 14	14,858	302
Aug. 22	143	5,169	Aug. 21	17,971	303
Aug. 30	3,289	9,770	Aug. 28	7,836	5,621
Sept. 3	6,249	7,978	Sept. 4	13,875	2,305
Sept. 5	11,652	207			
Pooled	25,371	22,312		55,262	9,326
Per cent	47	53		86	14

cranes to leave the area or resume migration earlier as long as alternative roosts are available. The increase in proportion of cranes observed in fields in the western two-thirds of the study area, the increase in the number of quarter sections occupied by cranes within the ground patrol area, and the relative increase in the number of treatments required adjacent to the untreated roosts demonstrated that the area used for foraging by sandhill cranes can be restricted, and that it can be assumed that cranes will forage in fields closest to their roosts. Lack of change in the mean number and mean frequency of occurrence of cranes per occupied quarter section, however, indicates constant requirements for food or space, or both, that are unaffected by acetylene exploder treatments.

Supplementary feeding space

The stubble of harvested commercial grain crops provides feeding space but its abundance varies with the progression of the harvest. As migrating cranes arrive on the Canadian Prairies before the grain harvest begins some additional grain supply is invariably required for cranes in locations such as Last Mountain Lake. Provision of feeding areas as alternatives to unthreshed commercial grain crops has been used in California since 1943 to meet the food and space requirements of ducks and to prevent duck damage (Horn, 1949). These alternative areas are frequently called "lure crops" if seeded for the specific purpose of feeding birds. Although imaginative, the term is not always descriptive because ducks are not necessarily lured to them. Feeding is effective for controlling duck damage when combined with scaring methods which will chase birds to lure grain. But one of the problems is to ensure that lure grain is eaten instead of commercial grain (Hammond, 1961). Obviously it is possible to supply too little grain or to have it in the wrong place.

Grain crops for cranes and ducks had been seeded on government land in the vicinity of Last Mountain Lake by Saskatchewan Department of Natural Resources as early as 1952, but no records were available of the procedures followed or of their effectiveness. Supplementary food has also been used to prevent duck damage to commercial grain crops near Portage la Prairie, Manitoba, but published accounts of the methods used or their effectiveness are not available.

Supplementary feeding areas or "lure crops" of unharvested grain were established during this study to estimate the feeding requirements when commercial grain crops are treated with acetylene exploders. In 1961 supplementary feeding areas were seeded on crown land, but in 1962 crops were added by purchase, and in 1963 by purchases and contracts (a new technique). Purchases and contracts increased the total undisturbed feeding area. This was desirable as the exact area required for feeding cranes was not known, and crown land available for seeding was limited, although additional arable land was acquired by the Wildlife Branch. All the lure crops were located within 1 mile of the major roosts in the northernmost 5 miles of Last Mountain Lake (Figs. 3, 4, and 5).

Our purchase under a contract was, essentially, that part of a crop that was eaten or otherwise made unharvestable by foraging birds. The terms of the agreement were that the farmer would allow cranes and other migratory birds to forage in his commercial crops unmolested, that he would harvest his crop as soon as possible, and would be paid for grain damage up to a maximum of $1,000 per quarter section. If the damage was likely to exceed that value before the crop could be harvested, the crop would be treated at no expense to the farmer or the value of the contract could be increased. Damage was assessed by a qualified insurance adjuster of the farmer's choice. In 1963 such contracts were made on nine quarter sections containing 577 acres of grain, all of which had been treated with acetylene exploders in previous years. Payments totalling $1,159.65 were made for damage to 169 acres in three of the quarter sections. In addition, one on which a payment was made was treated with an acetylene exploder.

One of the two grain crops purchased outright was 200 acres of wheat that had been damaged by hail in 1962. We paid only $725 for the remaining standing crop but it provided excellent forage for both cranes and ducks. The other crop purchased was 60 acres of swathed wheat for which we paid the commercial value of $2,082.

The provincial crown land used for lure crops is administered by the Wildlife Branch of the Saskatchewan Department of Natural Resources. The acreages seeded and the rotations followed in cultivation of 460 acres are shown in Table 15. At the beginning of the study only 60 acres (in 13-28-24-W2), seeded previously as a crane and duck feeding area, were available. An additional 50 acres of native prairie (in 18-28-23-W2) were cultivated and seeded to grain in 1961, and in the autumn an adjacent 50 acres of native prairie (in 18-28-23-W2) were cultivated in preparation for seeding in 1962. An additional 100 cultivated acres

TABLE 15 Crop rotations of crown land seeded for lure crops

Location	Total cultivated acreage	1961 crops	1962 crops	1963 crops
13-28-24 W2	60	60 ac barley	30 ac Prolific rye 30 ac summer fallow to fall rye	30 ac fall rye* 30 ac summer fallow
18-28-23 W2	100†	50 ac barley	25 ac Thatcher wheat 25 ac Garnet wheat 50 ac summer fallow	50 ac volunteer wheat 50 ac Olli barley
SE 21-28-23 W2	100	Not crown owned	50 ac Olli barley 50 ac summer fallow	100 ac Olli barley
E 1/2 24-28-24 W2	200	Not crown owned	Not crown owned	200 ac Olli barley

*Variety not mentioned indicates seed used by contractors was of local origin and not certified.
†Fifty acres of native prairie put into cultivation in spring of 1961 and an additional fifty acres put into cultivation in spring of 1962.

TABLE 16 Harvesting progress, acreage of lure crops, and number of acetylene exploder treatments applied

Year	Threshing commenced	Threshing general	Acreage supplementary feeding	Number exploder treatments applied
1961	August 12	August 17	110 acres	31*
1962	August 23	September 7	330 acres	58
1963	August 21	August 30	659 acres†	19

*Treatments in the eastern third of the study area not included, so that areas are comparable for each year.
†Not including those crops under contract for which no payments were made.

were acquired (in SE 21-28-23-W2) in 1962 and 200 more (in E ½ 24-28-24-W2) in 1963.

It has been mentioned that cranes excluded from commercial grain crops by acetylene exploder treatments were diverted to untreated fields. New treatments were applied if cranes went to unharvested grain, but not if they were diverted to stubble fields or lure crops. The number of treatments required should therefore be inversely proportional to the available supplementary feeding areas and stubble fields.

Crop reports of the Saskatchewan Department of Agriculture give the date of particular stages of the harvesting operations for wheat and indicate the number of stubble fields available. August 17, the date that threshing was general in the Last Mountain Lake district in 1961, was the earliest in the 26-year-period 1938–1963 (Table 7). In 1963 threshing was general on August 30, which is about the modal date; but in 1962 threshing was general on September 7, which is about a week later than usual. At the time crane populations reach peak numbers, in the third week of August each year, there were fewer stubble fields in 1962 than in 1961, so that the probability of cranes landing in an unharvested crop was greater in 1962 than in 1961. The increase in the number of treatments required in 1962 compared with 1961 demonstrates that relationship (Table 16). Threshing was general at a later date in 1963 than in 1961 so that a greater number of treatments would be expected then as well. The fewer treatments actually required in 1963 compared with 1961 were associated with increased acreage of supplementary feeding areas (Table 16).

An increase in the mean number of crane landings

TABLE 17 Cranes landing in lure crops

	1962			1963		
Location	Total cranes landing	Number days occurring	Days observed	Total cranes landing	Number days occurring	Days observed
13-28-24 W2	103	7	26	3,189	21	31
18-28-23 W2	1,670	10	28	2,026	26	31
21-28-23 W2	10,382	16	29	108,931	31	31
24-28-24 W2	—	—	—	24,563	23	31
Total	11,165	33	83	138,709	101	124

in lure crops (Table 17) was noted with increased acreage of lure crops and correlated with a decrease in the number and mean duration of treatments to commercial crops. In 1962, with 330 acres of lure crops and 58 treatments for a mean of 23.5 days, a mean of 338 crane arrivals per day occurred with a mean frequency of 11 days during observation of three crops for a pooled total of 83 days. In 1963, with a total of 659 acres of lure crops and 19 treatments for a mean of 11.0 days, a mean of 1,373 crane arrivals per day occurred with a mean frequency of 25 days during observation of four crops for a pooled total of 124 days. The maximum density observed was 4,365 cranes in 100 acres. Peak numbers (more than 4,000 cranes in the same field (100 acres of swathed barley in SE 21-28-23-W2) occurred on August 17, 18, 19, and 20, 1963.

Crane damage is an annual problem at Last Mountain Lake. Both supplementary feeding and acetylene exploder treatments were required in 1961, which was the earliest harvest season in the 26 years 1938–63. The number of acetylene exploder treatments required to prevent damage is related to the amount of alternative feeding space available, but there will be an optimum combination of exploder treatments and supplementary feeding areas which will minimize damage to commercial crops. There is certainly a maximum possible density of cranes per acre, which is related to the food and space requirements of cranes and governs the supplementary feeding area required.

Food requirements

Collected specimens

Although consumption of grain by sandhill cranes results in damage to commercial crops, little was known previously of the proportion of cranes that eat grain or of the amounts eaten. Fifty-four per cent of the total wet volume of stomach and crop contents of four cranes collected at Last Mountain Lake in 1947 was wheat, the most common grain in the area (Munro, 1950). Gollop (pers. comm.) reported that grain was the predominant item in the diet of three cranes collected in September 1958 at Last Mountain Lake and of three others shot in September 1960 near Kindersley, Saskatchewan. During the present study, food was measured from gullet contents of cranes shot for specimens.

During the spring and autumn of 1961, 1962, and 1963, sandhill cranes passing between fields and roosting areas at Last Mountain Lake were collected. Gullets of 157 specimens were removed and preserved in a solution of nine parts 70 per cent alcohol and one part formalin. The samples were dried at 60°C for 48 hours, and weighed to the nearest 0.1 gram. The gullet contents were processed through the courtesy of Dr. P. Reigert of the Canada Department of Agriculture Research Station, Saskatoon. The gullets of an additional 33 cranes were examined in the field but not weighed.

Grain was present in 93 per cent of the 190 gullets examined. One contained only grass, insects, and grit, and twelve were empty. Weights of the gullet contents provided an estimate of the minimum daily consumption of grain, although unknown variables such as the number of meals per day, digestion rate, and the time elapsed since ingestion limited the inferences that could be drawn. The mean weight of grain in 148 preserved gullets was 27.3 ± 18.4 (SD) grams but ranged from 0.7 to 85.5 grams. The grain found in these gullets was predominantly wheat, although barley was found in six samples and oats in one. The gullets seemed to contain one kind of grain, either wheat, barley, or oats.

Captive specimens

Two cranes captured in the autumn of 1962, and a third captured in the autumn of 1963, were kept in heated pens at the Saskatchewan Game Farm, near Saskatoon, where their food consumption was measured. In the winter of 1962–63 the cranes were kept in one pen, but the following winter the three cranes were housed separately. During the winter of 1963–64 each crane was weighed to the nearest 0.1 kilogram at intervals of about 1 month.

The cranes were fed wheat and commercial poultry mash placed in 4-gallon pails, filled about half way to the top so that spillage was minimized. The original supplies of food plus the pails weighed 25.0 pounds for wheat, and 20.0 pounds for mash. When periodically replenished to those levels, the pails plus contents were weighed to the nearest 0.1 pound to measure the amount consumed. Fresh water was supplied. Volumes of wheat and mash supplied were estimated by weighing six 1-quart samples of each to the nearest gram.

The three cranes ate a total of 128.1 pounds of wheat and 55.8 pounds of mash during a pooled total of 653 days (Table 18). The mean of six samples of wheat weighed 875.0 ± 0.62 (SE) grams per quart, and of six samples of mash 668.0 ± 0.31 (SE) grams per quart. The mean daily volume of food eaten was equivalent to that of 118.6 grams of wheat, and the total volume was equivalent to 3.26 bushels of wheat.

Two of the cranes (numbers 1 and 3, Table 18) ate mostly wheat. The third (number 2) ate mostly wheat in the winter of 1962–63 but predominantly mash in the winter of 1963–64. All cranes lost weight on this diet (Table 19), but the two that ate mostly wheat lost proportionately more and eventually died. Autopsy showed a lack of subcutaneous fat in both cranes, although crane number 1 had abundant visceral fat. Crane number 1 also developed an unusual plumage condition: all the contour feathers except a few on the head disappeared, so that only the primary feathers and down remained. The contour feathers apparently were eaten, as they were not in the pen.

The mean daily consumption by captive cranes was more than four times the mean weight of grain found in the gullets of shot specimens. Part of this discrepancy may be accounted for if it is assumed that cranes eat two meals per day. The remainder may be attributed to digestion of part of the grain before cranes were shot, or abnormally high consumption of grain by the captive cranes, or both. Loss of weight by all captive cranes, plumage aberrations, and postmortem condition of the two cranes that ate mostly wheat indicate that cranes were under nutritional stress and may have compensated by eating more than they normally would. However, if cranes foraging in fields eat no more than the captives in this sample, it would still take at least 200 cranes to eat 1 bushel of grain per day (653 crane-days)/3.26 bushels. As 350,000 crane-days accumulate at Last Mountain Lake in an average year before threshing is general, a maximum of 1,750 bushels of grain is required to supply their daily foraging needs. The average yield in the Last Mountain Lake crop district in the 10-year-period 1953–62 was 16.8 bushels per acre for wheat and 24.0 bushels per acre for barley. So the food requirements of as many as 18,000 cranes could be satisfied by wheat grown on 105 acres or by barley grown on 73 acres. But the maximum observed was only 4,365 cranes in 100 acres, suggesting the birds require space as well as food.

TABLE 18 Consumption of wheat and commercial poultry mash by three captive sandhill cranes

Year	Crane number	Elapsed time	Wheat eaten, lbs.	Mash eaten, lbs.
1962–63	1	91 days	51.6	7.7
	2	91 days		
1963–64	1	183 days	45.0	0.4
	2	183 days	10.7	47.6
	3	105 days	20.8	0.1
Total		653 days	128.1	55.8

Space requirements of sandhill cranes

Flock distributions

Damage to grain fields is related to location of flocks, the frequency with which flocks occur, and the numbers of cranes in the flock. Prior to this study there was little information on the spatial and temporal distribution and size of flocks for any segment of the crane population. Munro (1950) stated that cranes at Last Mountain Lake were not usually seen more than 2 miles from water. Walkinshaw (1949) reported flocks of 2 to 200 cranes 4 to 10 miles from roosts in Texas in winter and flocks of 2 to 45 cranes ½ to 3 miles from roosts in Michigan in autumn. Observed densities of cranes indicated the need for more information on spatial dispersion of flocks as well as a basis for predicting where and how frequently flocks of cranes are likely to occur.

Most of the flocks observed during census patrols consisted of 100 cranes or fewer, and more than 1,000 cranes per quarter section were recorded on only 46 of 2,852 observations (Fig. 18). The mean flock size was 185 cranes per occupied untreated quarter section (Table 11). Mean density varied with distance from major roosts, from 248 in quarter sections in the first mile, to 173 in the second,

TABLE 19 Weights of three captive sandhill cranes on diet of wheat and commercial poultry mash

	Crane No. 1		Crane No. 2		Crane No. 3	
Date	Weight, kg.	Change, %	Weight, kg.	Change, %	Weight, kg.	Change, %
Nov. 26/63	3.20	N.A.	3.71	N.A.	3.29	N.A.
Jan. 9/64	2.77	−13.4	3.83	+3.2	3.00	− 8.8
Feb. 3/64	2.81	−12.2	3.58	−3.5	2.80	−14.9
Feb. 13/64	2.77	−13.4	3.65	−1.6	2.43*	−26.1
Mar. 4/64	2.69†	−15.9	3.66	−1.3		

N.A. = not applicable.
*Postmortem weight taken within 12 hours of death.
†Crane No. 1 died May 31, 1964.

TABLE 20 Numbers and occurrences of cranes at various distances from major roosts

	1 mile*		2 miles		3 miles		More than 3 miles†	
	Total	Mean	Total	Mean	Total	Mean	Total	Mean
Number cranes..............	247,358	248	159,229	173	91,668	143	20,511	85
Occurrences.................	999	7	918	5	639	4	241	3
Number quarters............	146		181		153		81	

*Observations of cranes in lure crops not included with these samples.
†1961 observations only.

TABLE 21 Occurrences and numbers of cranes observed in morning and afternoon

	Morning		Afternoon	
	Occurrences	Numbers	Occurrences	Numbers
1961*	591	86,530	443	110,982
1962	323	53,095	191	47,582
1963	604	116,812	404	83,254
Pooled	1,518†	256,437‡	1,038†	241,818‡
Mean		169		233

*Includes only the part of the study area within 3 miles of Last Mountain Lake.
†t=7.80 with 2 d.f.
‡t=0.2909 with 2 d.f.

TABLE 22 Occurrences and numbers of cranes observed during morning and afternoon at various distances from major roosts

	Morning			Afternoon		
Miles	Occurrences	Total numbers	Mean	Occurrences	Total numbers	Mean
1	488	100,818	206	511	146,540	287
2	567	88,455	156	351	70,774	201
3	463	67,164	145	176	24,504	139
Pooled	1,518	256,437		1,038	241,818	

to 143 in the third, and to 85 in quarter sections more than 3 miles from major roosts (Table 20). There was a significant difference (t=7.80, 2 d.f.) in the frequency of occurrence of cranes but not in total number observed in the morning and afternoon; mean flock size was 169 in the morning and 233 in the afternoon (Table 21). An interrelationship among flock size, distance from roost, and time of day was observed in which the largest flocks tend to occur in the afternoon in fields closer to roosts (Table 22). There was no significant difference ("t" test) in the size of flocks leaving roosts in the morning and the afternoon (Table 23), but it was apparent that cranes left roosts in small flocks and formed larger flocks in fields.

Although some behavioural mechanism is operat-

Figure 18 Observed frequency of cranes per quarter section.

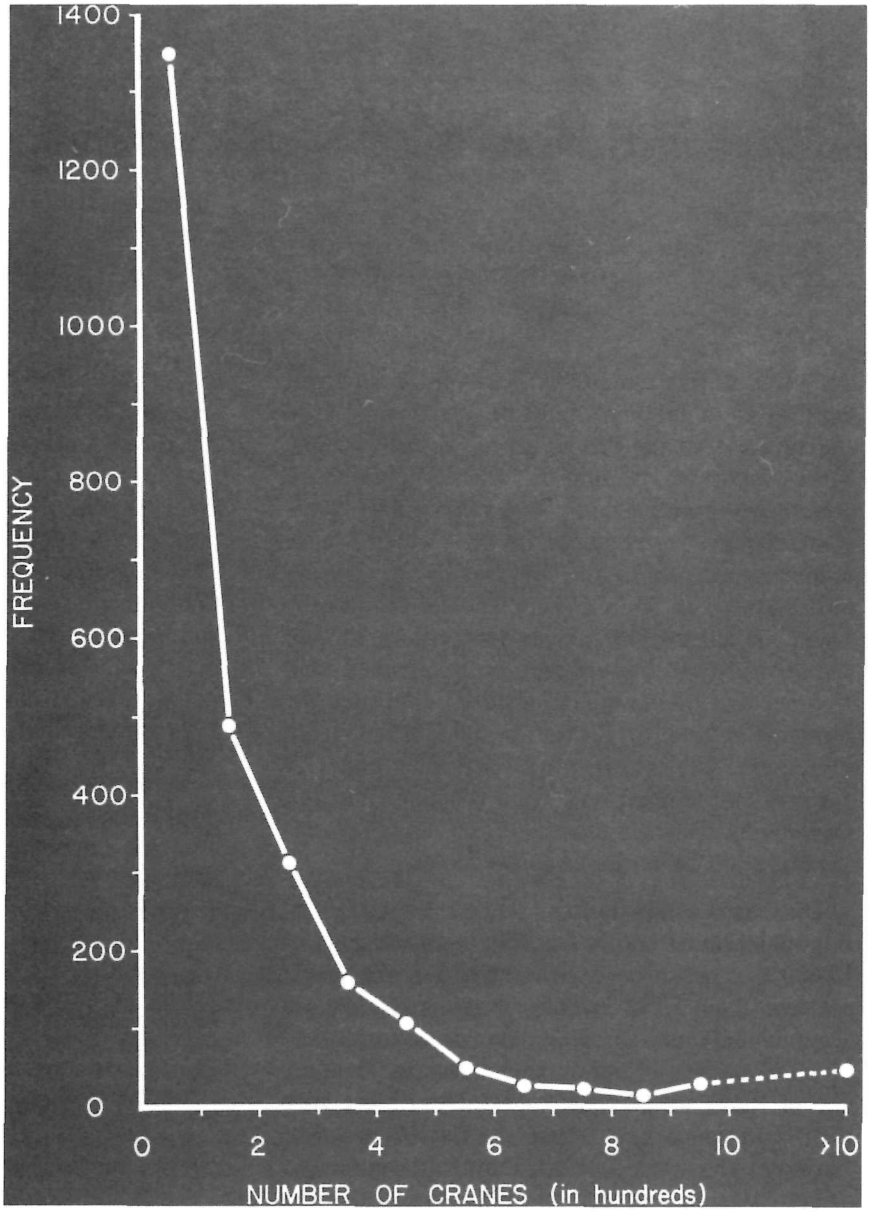


TABLE 23 Frequency distribution of size of 990 groups of cranes leaving roosts

Number in group	Observed frequency, a.m.		Observed frequency, p.m.		Pooled	
	Frequency	%	Frequency	%	Frequency	%
1	33	5.03	12	3.59	45	4.54
2	181	27.59	80	23.95	261	26.36
3	129	19.66	65	19.46	194	19.60
4	93	14.18	52	15.57	145	14.65
5	47	7.16	33	9.88	80	8.08
6	57	8.69	21	6.29	78	7.88
7	27	4.12	11	3.29	38	3.84
8	24	3.68	17	5.09	41	4.14
9	15	2.29	8	2.39	23	2.32
10	10	1.52	5	1.50	15	1.52
11	7	1.07	4	1.20	11	1.11
12	10	1.53	6	1.79	16	1.62
13	3	.46	2	.60	5	.50
14	6	.92	5	1.50	11	1.11
15	2	.30	1	.30	3	.30
16	3	.46	1	.30	4	.40
17	1	.15	1	.30	2	.20
18	3	.46	3	.90	6	.60
19	0	0	2	.60	2	.20
20	1	.15	0	0	1	.10
21	0	0	1	.30	1	.10
23	1	.15	1	.30	2	.20
25	1	.15	1	.30	2	.20
26	0	0	1	.30	1	.10
30	1	.15	1	.30	2	.20
55	1	.15	0	0	1	.10
	656	100.00	334	100.00	990	100.00

ing which affects the size of flocks in commercial grain fields at different times of day, it is of little consequence to the farmer when damage occurs. More important to him is whether cranes are present or absent. Cranes were observed or treatments required on 59 quarter sections within 3 miles of major roosts on Last Mountain Lake in all years of this study, on 93 in 2 years, and on 115 in only 1 year. Of this total of 267 quarter sections, 30 were uncultivated and 7 were lure crops. Cranes used 98.4 per cent of the quarter sections cultivated for commercial grain production in the first mile from roosts, 84.5 per cent in the second mile, and 71.4 per cent in the third mile from roosts (Table 24). Damage by cranes is most likely to occur in commercial grain fields closest to the roosts.

Dispersion within flocks

A population of cranes reaching peak numbers of 18,000, and present over a period of 3 weeks, would eat less than 1,750 bushels of grain in 350,000 accumulated crane foraging days. An average yield of 1,750 bushels of barley would require 73 acres, and of wheat would require 104 acres, in the crop district in which Last Mountain Lake is situated. However, the mean observed number of cranes per quarter section was 185, and more than 1,000 per quarter section were observed on only 46 occasions (Fig. 18), indicating that foraging requirements are not directly proportional to food availability, and that foraging cranes might have a spatial requirement exceeding that imposed by food supply. In populations of known density the distance from each individual to its nearest neighbour may be used to obtain a measure of spacing of individuals (Clark and Evans, 1954). The density of crane populations in grain fields was computed from aerial photographs taken at an altitude of 800 feet. A Williamson F-24 camera equipped with a lens of 8-inch focal

TABLE 24 Distribution of quarter sections used by foraging cranes

	Distance from major roosts on Last Mountain Lake in miles		
	1	2	3
Number of quarters used....	82	101	84
Number of cultivated quarters................	65	110	112
Number cultivated quarters used...........	64	93	80
Per cent cultivated quarters used............	98.4	84.5	71.4
Number uncultivated quarters used............	18	8	4

length was positioned in a port in the bottom of the fuselage of a light aircraft. It was determined in 1962 that cranes do not shift their position on the ground during passage of an aircraft overhead at an altitude of 800 feet.

The images of cranes appearing on photographs were counted by punching them lightly with a needle attached to an electric counter. The area occupied by the flock was measured with a planimeter by following lines joining images of individual cranes on the margins of flocks. The prints had been enlarged to a scale of about 1 inch : 60 feet because the scale of the negatives was too small for the measuring required. The scale of the original photographs was determined from images of known reference points on the ground, and the enlargements from projected marks on the original prints. Distances between centres of images of cranes on the enlarged prints were measured with dividers to the nearest 1/60th of an inch, so that measurements of distances between cranes were to the nearest foot.

Clark and Evans (1954) used mean distances to nearest neighbour relative to population density to measure the distribution pattern of a population. Many important ecological concepts of practical significance are based on the assumption that individuals of most populations are distributed at random. The Clark-Evans method was developed to provide a simplified measure of the degree of departure from a random distribution, and of the significance of differences in the distribution pattern of two or more populations.

If a population is distributed at random, the expected mean distance between individuals and their nearest neighbours ($\bar{r}_E$) is equal to $1/(2\sqrt{\rho})$, where ρ is the density of the population calculated in the same units used in measuring the distance between neighbours. The ratio of actual mean distance between neighbours ($\bar{r}_A$) to the expected is given by $R=\bar{r}_A/\bar{r}_E$. In a random distribution $R=1.0000$ (Clark and Evans, 1954). In a perfectly uniform distribution the expected mean distance between neighbours will be maximized and will have the value $\bar{r}_E=1.0746/\sqrt{\rho}$ and the ratio of actual mean distance between neighbours to the expected is $R=\bar{r}_A/\bar{r}_E=2.1491$ (Clark and Evans, 1954). The ratio of actual to expected values (R) is a measure of departure from randomness, the significance of which may be tested by the normal variate $c=(\bar{r}_E-\bar{r}_A)/\sigma\bar{r}_E$, where $\sigma\bar{r}_E$, the standard error of $\bar{r}_E$, is $0.26136/\sqrt{N\rho}$, where N is the number of measurements of distance taken. The magnitude of R indicates the direction of departure toward perfectly uniform distributions with values greater than 1 or completely aggregated distributions with values less than 1.

TABLE 25 Frequency distribution of individual distances of 1,326 cranes in 29 foraging flocks

Distance (nearest 1 ft.)	Observed frequency	Per cent frequency
1	0	
2	4	.30
3	107	8.07
4	243	18.32
5	365	27.53
6	262	19.76
7	128	9.65
8	91	6.86
9	43	3.24
10	25	1.88
11	19	1.43
12	15	1.13
13	6	.45
14	4	.30
15	3	.23
16	2	.15
17	1	.08
18	1	.08
19	2	.15
20	3	.23
21	0	
22	1	.08
23	0	
24	1	.08
25	0	

Density is by definition the number of individuals per unit area. The areas referred to must be selected with care, as a set of points may be random in one specified area but nonrandom in a larger area (Clark and Evans, 1954). For this reason the area taken to be occupied by cranes was within a line joining the images of cranes on the perimeters of the flocks appearing in photographs. From the relationships defined by Clark and Evans, the number of cranes per unit area in a random dispersion and a perfectly uniform dispersion can be expressed in terms of the observed mean distance between neighbours as follows:

in a random dispersion,

$$\bar{r}_A=1/(2\sqrt{\rho})$$

in a uniform dispersion,

$$\bar{r}_A=(1.0746/\sqrt{\rho})\ 2.1491=2.3094/\sqrt{\rho}.$$

As $\rho=x/y$, where x = number of cranes and y = the area occupied in square feet, the following relationships may be derived:

in a random dispersion, $y=(2\bar{r}_A)^2x$

in a uniform dispersion, $y=(\bar{r}_A)^2x/5.3333$.

These are equations of the form $y=ax$, and may be plotted using the appropriate mean distance between neighbours to indicate the predicted area occupied by different numbers of cranes if randomly and uniformly dispersed.

Distances between 1,326 cranes in 29 foraging flocks were found to be not less than 2 feet and not more than 24 feet (Table 25) with a mean of 5.79 ± 0.1622 (SE) feet. Although the distribution of distances was slightly skewed, it was very regular and markedly peaked, indicating that maintenance of 4 to 6 feet between individuals was predominant among the populations and within populations (Table 26). By substitution of 5.79 for $\bar{r}_A$ in the appropriate equations above, the predicted space occupied by cranes when randomly dispersed is described by the equation $y = 134.09\ x$, where y is the area in square feet and x is the number of cranes, and when uniformly dispersed by the equation $y = 6.29\ x$.

The space actually occupied by the 29 flocks was plotted in relation to the predicted areas for randomly and uniformly dispersed cranes (Fig. 19). By regression analysis the observations were described ($r = 0.965$) by the equation $\log y = 1.2183 + 1.3859 \log x$, or $y = 16.5\ x^{1.3859}$. The three lines in the figure describe random dispersion, uniform dispersion, and observed dispersion. Significant deviations from random dispersion occurred in all but three populations (Table 26), and a trend away from uniform spacing with increased numbers is apparent (Fig. 19). The hypothesis that observed densities of cranes in grain fields result from occupancy of habitat by individuals either randomly or uniformly dispersed must be rejected; the alternative hypothesis that area occupied by a group of cranes is more than the sum of the space requirements of individuals is therefore accepted.

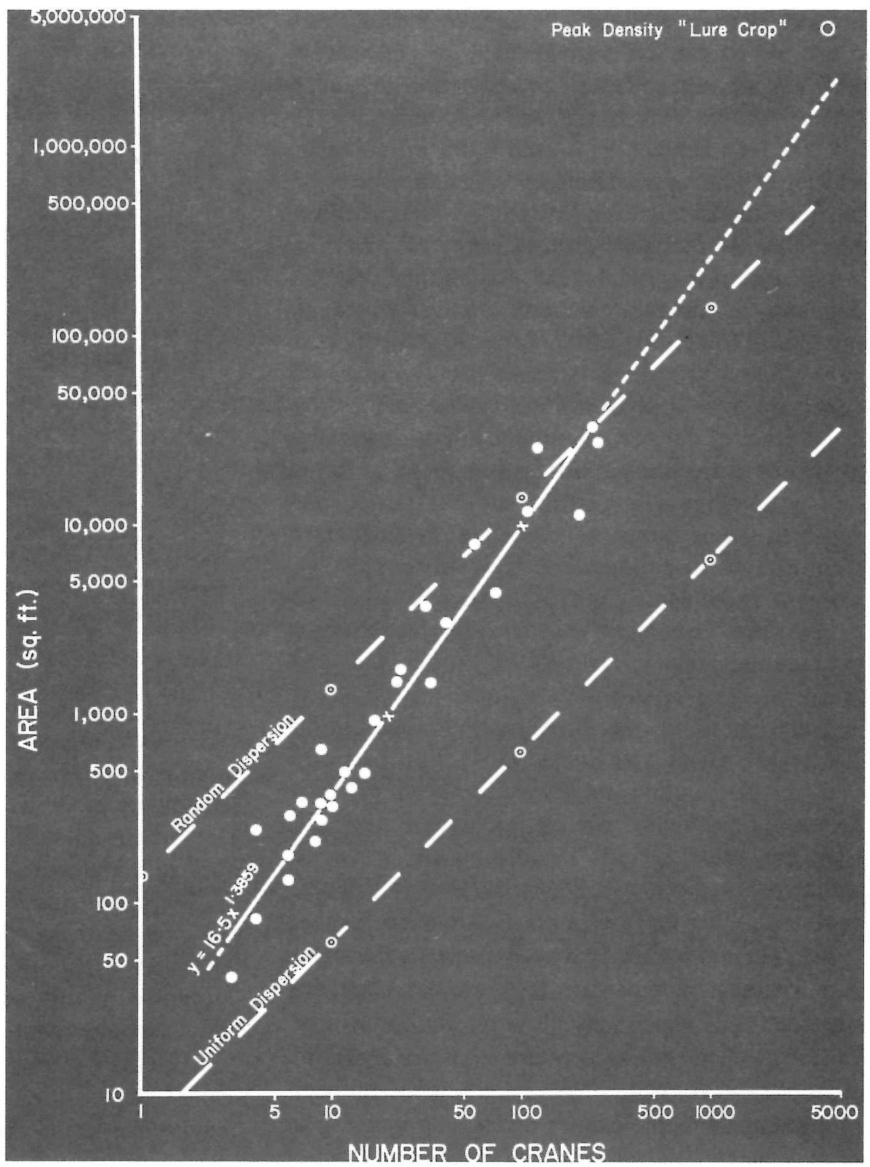
The implication of a space requirement of a group of animals as well as of individuals is that mean distance between individuals is not an adequate measure of the dispersion pattern of the population. Cranes are motile, moving across a field as they forage and moving from field to field. A minimum distance is maintained between cranes, indicating an "individual distance" referable to other cranes, but not to a fixed area or particular feature of the grain field. However, the individual

TABLE 26 Measurements of spacing in 29 foraging flocks of cranes

Flock	N	ρ	$\bar{r}_A$	$\bar{r}_E$	R	$\sigma_{\bar{r}_E}$	c
1	7	.0199	5.44	3.54	1.54	.7001	2.71**
2	10	.0298	4.74	2.90	1.63	.4788	3.84**
3	15	.0313	4.25	2.82	1.51	.3814	3.75**
4	12	.0241	5.02	3.22	1.56	.4860	3.70**
5	6	.0214	5.90	3.42	1.72	.7292	3.40**
6	9	.0261	4.58	3.09	1.48	.5392	2.76**
7	6	.0213	5.62	3.42	1.64	.7311	3.01**
8	9	.0137	5.94	4.27	1.39	.7438	2.24*
9	240	.0075	6.00	5.75	1.04	.1948	1.28
10	22	.0148	5.39	4.11	1.31	.4580	2.80**
11	9	.0322	4.33	2.78	1.56	.4854	3.19**
12	17	.0186	4.89	3.68	1.33	.4648	2.60**
13	31	.0085	4.96	5.44	0.91	.5092	0.94
14	4	.0108	9.10	4.81	1.89	.2577	3.41**
15	10	.0272	5.76	3.03	1.90	.5012	5.45**
16	121	.0049	7.32	7.14	1.02	.3394	0.53
17	24	.0136	5.33	4.27	1.25	.4574	2.32*
18	6	.0227	5.88	3.31	1.78	.7083	3.63**
19	73	.0167	5.95	3.88	1.54	.2367	8.74**
20	40	.0134	5.04	4.31	1.17	.3570	2.04*
21	3	.0400	4.77	2.50	1.91	.7545	3.01**
22	34	.0230	4.90	3.29	1.49	.2956	5.45**
23	8	.0377	4.56	2.58	1.77	.4759	4.16**
24	56	.0071	7.70	5.95	1.29	.4145	4.22**
25	176	.0160	4.88	3.97	1.23	.1557	5.84**
26	4	.0476	4.08	2.29	1.78	.5990	2.99**
27	13	.0310	4.56	2.84	1.61	.4117	4.18**
28	252	.0094	5.82	5.16	1.13	.1698	3.89**
29	109	.0096	5.85	5.10	1.15	.2555	2.94**

*Significant at 5 per cent level.
**Significant at 1 per cent level.

Figure 19 Observed distribution of areas occupied by crane populations.



distances do not describe the observed densities of cranes in grain fields. Extrapolation from the equation $y = 134.09\ x$ suggests that 32,500 cranes might be observed per 100 acres if randomly distributed, and from the equation $y = 6.29\ x$ that 715,300 cranes per 100 acres might be observed if uniformly distributed, but the maximum observed number was 4,365 cranes per 100 acres.

Population density

The hypothesis that area occupied by groups of foraging cranes is more than the sum of space requirements of individuals implies that a larger total population can exist in several small parcels of habitat than in an equivalent area of a few large parcels. The phenomenon of higher densities of animals in small areas than in large areas is well known and is usually attributed to differences in habitat quality, or to interspersion of habitat types, e.g., edge effect. Differences in caloric output, total digestible nutrient, or quality of other niche requirements can be demonstrated between habitats, but their relevance to population densities is usually based on assumptions, because of the difficulty of accurate population census. The topography at Last Mountain Lake is flat to gently rolling, grain fields are as uniform as modern agricultural technology allows, and photographed flocks of cranes were within the boundaries of the grain fields and were easily counted, so that differences in habitat quality were minimal and areas were easily related to numbers of cranes. The data nevertheless show a decrease in density with increase in crane numbers. It might be speculated that differences in habitat quality, within the range of tolerance of the species, are relatively unimportant and that population density is governed primarily by habitat quantities, particularly the number of parcels available to meet the needs of grouped animals for breeding, nesting, resting, feeding, and so on.

The effect of group behaviour on maximum densities and estimated space requirements of cranes is that less total acreage is required if the lure crops provided are small. As an example, it can be estimated from the equation $\log y = 1.2183 + 1.3859\ x$ (Fig. 19) that flocks of 200 cranes occupied an average of 0.6 acre each. Thus 22 flocks of 200 cranes would occupy a total of 13.6 acres, but extrapolation indicates that a single flock of 4,400 would occupy 42.5 acres. However, on the one occasion a flock as large as 4,365 was observed, it was in a field of 100 acres. Although the cranes were spread out in the field when observed, it is not possible to state whether more cranes would have actually occupied the field. Regression analysis of the measured areas occupied by photographed flocks including the observation of 4,365 per 100 acres is highly significant ($r = 0.984$), but lacking further evidence it is necessary to conclude that 4,365 cranes are the maximum that will occupy 100 acres.

This maximum number may be related to the number of cranes roosting nearby. Certainly the peak numbers observed in the lure crops occurred when peak numbers of cranes were counted roosting on Last Mountain Lake. As the peak population of 18,000 cranes was distributed over 11 roosts, and because cranes appear to forage in suitable fields closest to their roost, maximum densities of cranes may be obtained in small grain fields distributed close to roosts. Not more than 412 acres located within 1 mile of major roosts would be required for the peak population of 18,000 cranes, assuming that the fields were less than 100 acres in size. The 412 acres estimated to be required for cranes is less than was actually available in 1963. One of the crops (E ½ 24-28-24-W2) was 200 acres, and apparently more than optimum size as it was never completely occupied by cranes. Two others (13-28-24-W2 and 18-28-23-W2) were never used by flocks of more than 1,000 cranes at once, also suggesting suboptimum use by cranes, but were used frequently by flocks of ducks. Observations of ducks were not recorded systematically but an estimated 13,000 ducks were seen at one time on 18-28-23-W2. Potential use of lure crops by ducks at Last Mountain Lake must be recognized, but it seems that annual acreage of grain for supplementary feeding can be decreased from that used in 1963 and should be distributed close to all major roosts. However, consideration must be given to economic advisability before attempting to establish permanent lure crops.

Sandhill cranes can be prevented from landing in commercial grain crops by treatments with acetylene exploders, but are diverted to other fields and even to alternative roosts as the number and duration of treatments increase. Cranes do not leave the general area as long as alternative roosts are available, and diversion to other areas can be minimized by provision of supplementary feeding space in which cranes can forage unmolested close to roosts. With increases in number, total acreage, and isolation of lure crops from disturbance, crane use of lure crops increases and the number of treatments required in commercial crops decreases. However, there is a maximum density of cranes, which is related to the space requirements of foraging flocks and the number of cranes on adjacent roosts, but not directly influenced by the availability of grain. Damage to grain crops at Last Mountain Lake by sandhill cranes is a recurrent problem and some crops are susceptible to damage even in an early harvest year.

Consistently low yields limit grain production in the area, and reductions of yield caused by cranes must be considered within that framework. Wildlife insurance indemnities for duck and sandhill crane damage in the Last Mountain Lake study area in the five-year-period 1956–60 totalled $51, 517, or an annual average of $10,303. In 13 of the 25 years 1938–62, subsidies totalling $641,194, or averaging $25,645 annually, were paid under the provisions of the Prairie Farm Assistance Act. Because of low arability or low fertility, 68 per cent of the land is likely to produce less than 476 bushels of wheat per quarter section or less than 11.5 bushels per acre (Class I and II, Canada Department of Agriculture, Economic Classification of Land).

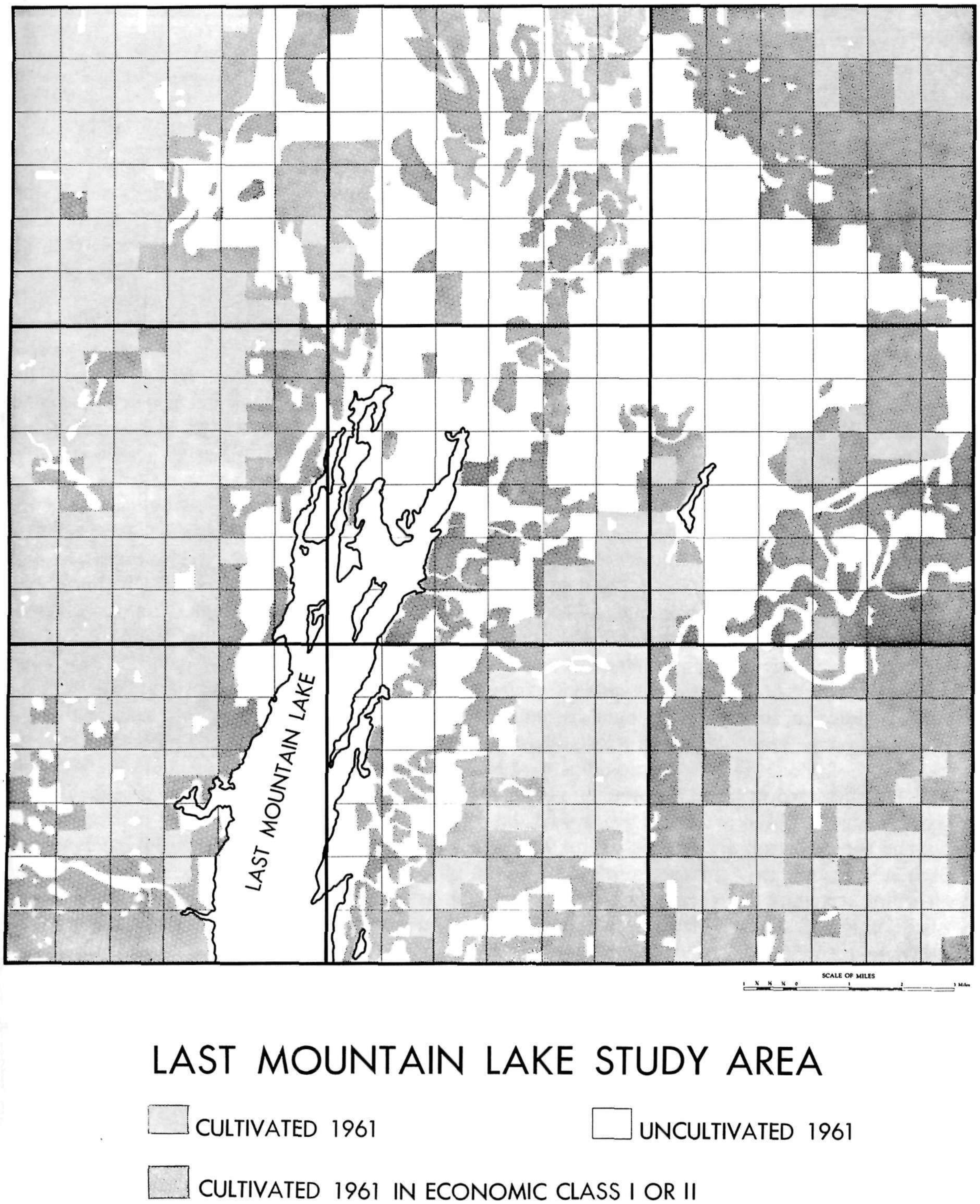
Wildlife damage to crops may occur on farms of low or high productive capability. The economic effects of damage are much more severe on farms of low production capability. For example, all the land adjacent to Last Mountain Lake, where susceptibility to damage is highest, is of low productivity (Fig. 20). On the poorest land (Class I), the average yield is less than 350 bushels of wheat per quarter section or less than 9.5 bushels per acre. The net return per quarter section is at most $285.54, if the average return for wheat is taken at $1.50 per bushel and the average cost is taken as $6.50 per acre (Guide to Farm Practice in Saskatchewan, 1960). If damage were $350 per quarter section, about the average indemnity for cranes, the entire profit on that quarter section would be lost. Part of the operating cost would have to be met from the profit on a quarter section not affected by damage. On the best land (Class V), none of which occurs in the area, the average production is over 900 bushels per quarter section and the average yield is 15.5 to 18.0 bushels per acre, so that net returns are at least $1,233 if the same assumptions are used. A farmer on Class V land might lose $350 profit to cranes, but would not face economic disaster.

Wildlife damage to land poorly suited for grain production is not unique to Last Mountain Lake. In the vicinity of Big Grass Marsh, Manitoba, and the Quill Lakes, Saskatchewan, cranes damage crops grown on poorly drained, alkaline, or sandy soils. In the northern parts of the grain-growing region, as at Meadow Lake, Saskatchewan, where fertility is not usually a problem, duck damage occurs to crops that are exposed to late harvests and frost hazards, so that susceptibility to damage by foraging ducks is increased by longer exposure and necessity for swathing (Stephen, 1961). Similar conditions appear to exist in other northern areas such as The Pas, Manitoba, and the Peace River district, Alberta.

Wildlife has an economic value which may be considered as an alternative to grain production. Where the margin on grain production is low, the value of wildlife need not be high to be a more suitable alternative. In the 1850's sandhill cranes were sold for $16 to $20 each in San Francisco when domestic turkeys were scarce (Walkinshaw, 1949). Cranes are no longer priced in a market. Their value now is primarily intangible, and thus cannot be expressed entirely in monetary terms. The mobility of cranes also poses difficulties in assigning values to the total population, or to particular segments of it, although a value attributable to cranes may be assigned to a particular place such as Last Mountain Lake. Considered as an alternative to grain production the value of cranes can be equated with the value of grain production foregone as a result of existence of cranes. Although this tangible value can be calculated independently of knowledge of the total numbers and distribution of cranes, it is an integral part of the total value, including intangible value, of the total crane population. The value of grain production foregone is either the cost of damage or the cost of its control, and this provides a basis for judgement of the economic value of sandhill cranes. The "best" value that can be put on cranes by this method is zero; that is with no loss of grain production. Although this may not be satisfying it is at least quantifying.

It is assumed that food requirements of cranes are about the same if cranes forage freely or if their foraging is restricted to a few fields. The damage caused, however, is greater if they forage freely, because of trampling which makes grain unharvestable while remaining edible to cranes. If cranes forage freely without lure crops, the value of grain production foregone can be calculated as the cost of damage or its control. If foraging of cranes is

Figure 20 Last Mountain Lake study area and cultivated Class I and Class II land.



restricted to lure crops which is itself a form of damage control, the cost can also be calculated and compared.

Wildlife insurance indemnities are a minimum measure of the cost of damage, because of limitations on insurability and reluctance of some farmers to purchase insurance. Payments for damage by cranes in the study area were made in 82 quarter sections, or an average of 16.4 annually, in the 5-year-period 1956–60. The average payment in that period was $356.28 (Table 1). Thus the damage attributed to cranes in the Last Mountain Lake study area averages at least $5,843 annually.

If all quarter sections susceptible to damage were treated with acetylene exploders, cranes would be displaced from one crop to another as shown in this study. As crops become harvested they are no longer susceptible to damage, thus limiting the number of treatments required. An estimate of the number of treatments needed is derived from the results observed in this study in 1962, when the harvest was later than normal. In that year, 50 quarter sections in two-thirds of the study area were treated up to September 1, the average date when threshing is general in the district. In addition to the treated fields, cranes fed unmolested in seven quarter sections on lure crops. If these crops had been commercial grain they also would have required treatment. The treatments needed are estimated at 86 $[\frac{3}{2}(50+7)]$ for the total study area for an average year. This assumes no undisturbed feeding in unharvested crops, and if that had actually been the case in 1962 the number of treatments needed would very likely have been higher than 50. Thus 86 can be considered a minimum figure for the number of treatments required in an average year without lure crops.

Acetylene exploders similar to the ones used in this study may be purchased complete with acetylene regulator for $159. If operated for a 10-year period without repairs (the machine is guaranteed for 2 years), the cost of the machine including 5 per cent interest on the investment would be $25.90 annually. A 5-day supply of acetylene costs $3.50; if the machine were operated for an average period of 16.1 days the annual cost for acetylene would be $11.27. If a deposit on the acetylene cylinder is required, an additional $1.25 attributed to 5 per cent interest on the $25 deposit must be added, making the average annual cost for acetylene $12.52. Replacement of eight type-D 1.5-volt dry cells every 2 years and two type-B 67.5-volt dry cells every 4 years prorated over the 10-year period was estimated to cost $3.53 annually. Installation of the exploder requires about 45 minutes, but two service trips and removal of the exploder require only 10 minutes each, so that the total labour required is 1¼ hours or $1.88 (at $1.50 per hour) for the time spent at the exploder site. The average annual cost of treating a quarter section with an acetylene exploder is therefore $43.83, compared with an average cost in areas suffering damage of $356.28 damage per quarter section.

The annual cost for 86 exploder treatments averages at least $3,769 compared to at least $5,843 for the cost of damage. Thus if cranes are allowed to forage only on stubble it is cheaper to control damage on unharvested crops with acetylene exploders than to pay for damage. Expressed in another way, the value of cranes is higher if their damage to grain is controlled with acetylene exploders than if they eat and trample commercial grain.

If foraging of sandhill cranes were restricted to lure crops, the crane population present until threshing is general in the study area would consume not more than 1,750 bushels of wheat. It is also estimated that 412 acres are required to accommodate peak numbers of cranes present during that time. If the cost of producing 1,750 bushels on 412 acres is taken as $8.25 per acre, as in this study (Table 27), then the cost of feeding cranes in lure crops is $3,399 annually. In an average year 45 treatments with acetylene exploders on roosts and in commercial grain crops costing $1,972 would restrict crane foraging to lure crops or stubble, assuming a distribution of feeding fields similar to that in the study area in 1963.

If lure crops were located on Class I land as at Last Mountain Lake, the average yield of wheat on 412 acres would be between 2,472 and 3,914 bushels (6.0 to 9.5 bushels per acre). It is unlikely that grain surplus to the 1,750 bushels required by cranes would be harvestable after cranes and ducks had foraged in the crops until September 1, but accommodation of ducks represents an additional benefit because it tends to reduce the cost of duck damage to commercial crops. The extent of the benefit is not known exactly, because ducks as well as cranes trample grain, and foraging in lure crops reduces losses in commercial crops attributable to both consumption and trampling. However, a minimum value may be assigned by considering the value of grain surplus to the cranes' requirements. The value of the 672 to 2,190 surplus bushels is

TABLE 27 Cost of lure crops

Year	Seeded crown land			Commercial crops purchased			Commercial crops contracted		
	Acres	Cost, $	Cost/ acre, $	Acres	Cost, $	Cost/ acre, $	Acres	Cost, $	Cost/ acre, $
1961...........	110	605.30*	5.50	—	—	—	—	—	—
1962...........	130	1525.30*	11.73	200	725.00	3.62	—	—	—
1963...........	430	3411.85	7.93	60	2082.00	34.70	169†	1159.65	6.94

*Does not include $250 for breaking up 50 acres of native prairie in each year.
†Contracts were made to cover 577 acres of crop, but payments were made for only 167 acres on which significant damage was assessed.

$2,146 if $1.50 is taken as the commercial value of wheat and 1,431 bushels as the average surplus. The cost of restricting foraging of cranes to a few fields then becomes $5,371 minus $2,146 or less than $3,225 annually. Further savings might accrue if higher yielding grain crops such as barley were grown for supplementary feeding, as more ducks might be fed on additional surplus bushels. There is no evidence that cranes or ducks prefer to eat wheat, or that they reject barley.

It is apparent that lure crops should be distributed close to all major roosts, although they presently are not. An additional benefit of restricting foraging of cranes would be reduction of annual subsidies for grain production if land presently farmed for grain were acquired for lure crops. The extent of that benefit would be assigned to further reduction of the $3,225 annual cost of crane foraging in lure crops.

The suitability for grain production of the area adjacent to Last Mountain Lake is so low that in any event consideration must be given to alternatives to grain production. Commercial grain crops within 1 mile of major roosts are highly susceptible to damage, and those close to lure crops will be even more so. If lure crops are expanded there will be ample opportunity for development of other resource values, such as forage for cattle and outdoor recreation, as it is apparent that lure crops should be small. The values of future resource development at Last Mountain Lake cannot properly by attributed to the present costs of restricting the foraging of sandhill cranes, but those values are not impaired by lure crops, and the possibilities for forage and recreation development are enhanced.

This study has shown that control of damage to grain crops by sandhill cranes is feasible and economically advisable, because "higher" value can be assigned to cranes when damage is controlled, and because of the severity of the economic effect of damage on low productivity farming operations in areas such as those near Last Mountain Lake. The recreational value of the sandhill crane resource should be developed. For example, limited hunting of cranes is possible and was permitted in 1964 and 1965 in parts of western Canada after a close season of 46 years. Such hunting will have little effect on reduction of crop damage. The fear of reducing the numbers of greater sandhill cranes is unfounded, but if hunting is resumed on an annual basis it must be managed carefully to minimize the possible danger to whooping cranes and to avoid depletion of the sandhill crane population.

Sommaire

1. Les populations à l'état sauvage d'oiseaux protégés par la loi, tels que les grues canadiennes et les canards, font des dégâts dans les grandes cultures en consommant et en couchant au sol les céréales mûres encore sur pied. De 1961 à 1963, à l'extrémité nord du lac de la Dernière-Montagne, en Saskatchewan, on a fait des études sur les moyens à prendre pour réduire au minimum les dégâts causés aux champs de céréales, particulièrement par les grues canadiennes.

2. Les fermes touchées par les dégâts des grues sont dispersées dans une large zone à travers les Prairies canadiennes. Les dégâts sont importants parce qu'ils surviennent d'année en année sur des fermes à faible rendement céréalier et à faible marge de profit. La venue présumée d'une rare sous-espèce, la grande grue canadienne, ainsi que des raisons d'esthétique, ont amené l'interdiction de la chasse aux grues pendant 46 ans, jusqu'en 1964.

3. Les grues causent des dégâts lors de leur migration d'automne. D'après les seuls critères taxonomiques, il a été impossible de distinguer la grande grue canadienne parmi les oiseaux migrateurs d'automne ou de printemps au lac de la Dernière-Montagne.

4. Les migrateurs d'automne arrivent au lac de la Dernière-Montagne pendant la première semaine d'août. Leur effectif atteint un sommet d'environ 18,000 grues pendant la troisième semaine d'août et demeure à peu près le même jusqu'à la mi-septembre. Leur nombre diminue ensuite jusqu'au départ des dernières grues après la mi-octobre. Le nombre cumulatif moyen de jours-grue avant que le battage des céréales ne se généralise dans la région du lac de la Dernière-Montagne, est estimé à 350,000.

5. L'installation de détonateurs automatiques à l'acétylène dans certains quarts de section y a abaissé sensiblement le nombre moyen des grues et la fréquence moyenne de leurs séjours, par rapport aux quarts de section laissés sans détonateurs. Les scientifiques ont établi un rapport entre la répartition des grues dans les champs de céréales et leurs habitats, d'une part, et le nombre et la durée des traitements aux détonateurs, d'autre part, et tous ces facteurs ont été reliés à la superficie d'aires d'alimentation disponibles. Le nombre total des grues dans la région n'a pas changé, toutefois.

6. On trouva du grain dans le jabot de 93 p. 100 des 190 spécimens abattus. La consommation de nourriture des grues sauvages en captivité montra qu'un boisseau de blé suffit à nourrir 200 grues par jour.

7. Le maximum de grues relevé en train de fourrager dans les champs de céréales était de 4,365 par cent acres. Mais on les apercevait le plus fréquemment en troupeaux de cent ou moins par quart de section. La distance moyenne observée entre les grues individuelles fourrageant dans les champs de céréales était de 5.79 ± 0.1622 (E.-T.) pieds. Mais l'aire occupée par chaque grue était insuffisante pour décrire pleinement les dispersions observées.

8. Les besoins minimums de fourrage de la population de grues du lac de la Dernière-Montagne exigeraient 412 acres, si les champs de céréales avaient moins de 100 acres chacun. Les grues fourragent surtout dans les champs de céréales qui sont les plus proches de leurs principaux habitats.

9. Les terres les plus exposées aux dégâts au lac de la Dernière-Montagne ont un faible rendement en céréales. Le coût de prévention des dégâts au moyen de détonateurs à l'acétylène est estimé à $43.83 par an et par quart de section. Le coût global de traitement de tous les quarts de section menacés serait en moyenne d'au moins $3,769 par an. Mais en l'absence de traitement, le coût annuel moyen des dégâts serait de $5,843. Si l'on combine l'emploi de détonateurs à l'acétylène et les mesures visant à ménager aux grues des pâtures d'appoint, mises à l'essai au cours de la présente étude, le coût pourrait être réduit à moins de $3,225 par an.

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