COMPARATIVE BREEDING ECOLOGY OF LESSER SANDHILL CRANES (*GRUS CANADENSIS CANADENSIS*) AND SIBERIAN CRANES (*G. LEUCOGERANUS*) IN EASTERN SIBERIA

A Dissertation

by

TSUYOSHI WATANABE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2006

Major Subject: Wildlife and Fisheries Sciences

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ABSTRACT

Comparative Breeding Ecology of Lesser Sandhill Cranes (*Grus canadensis canadensis*) and Siberian Cranes (*G. leucogeranus*) in Eastern Siberia. (December 2006)

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Populations of Lesser Sandhill Crane (*Grus canadensis canadensis*) have been increasing during the last decades in Eastern Siberia, an area historically known as breeding grounds of endangered Siberian Cranes (*G. leucogeranus*). Significant overlap in niche dimensions between the two species may occur and could lead to competition between them. Therefore, this study of comparative breeding ecology of common Lesser Sandhill Cranes and endangered Siberian Cranes was performed.

From late May to early August 2000, I studied Lesser Sandhill and Siberian cranes within a 30,000-ha part of Kytalyk Resource Reserve in the Republic of Sakha (Yakutia), Russia. My main objective was to compare dispersion patterns and resource use of breeding Lesser Sandhill and Siberian cranes in areas of distribution overlap.

Lesser Sandhill Cranes used moderate-wet (polygon) areas as their nest sites and main foraging areas, where terrestrial foods were scattered. In contrast, Siberian Cranes were nesting and foraging on low-basin wet areas, where aquatic foods were concentrated and dominant. Inter-nest distances were less for heterospecific cranes than for conspecific cranes, and more territorial behavior was projected toward conspecifics than toward heterospecifics. Lesser Sandhill Cranes were more mobile and used moderate-wet (polygon) areas more than Siberian Cranes; however, both species spent similar time foraging and being alert.

The two crane species used different vegetation types for nesting and foraging, had different time-activity budgets, and used different resources in the Siberian tundra. While the population of Lesser Sandhill Cranes in the study area has the potential to increase, both species may simultaneously share the same geographic area due to differences in ecological requirements.

DEDICATION

To my parents, Toru and Michiko Watanabe

For their encouragement, understanding, and endless support

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CHAPTER I

INTRODUCTION

SANDHILL CRANE AND SIBERIAN CRANE

Sandhill Crane: subspecies and populations

The Sandhill Crane (*Grus canadensis*) is the most abundant of the world's cranes with a total estimated population of more than 520,000 (Meine and Archibald 1996). Six subspecies are recognized based on morphometry and the geographic separation of breeding sites: Lesser Sandhill Crane (*G. c. canadensis*), Canadian Sandhill Crane (*G. c. rowani*), Greater Sandhill Crane (*G. c. tabida*), Florida Sandhill Crane (*G. c. pratensis*), Mississippi Sandhill Crane (*G. c. pulla*), and Cuban Sandhill Crane (*G. c. nesiotes*). The taxonomic status and relationships among the Sandhill Crane subspecies have been discussed frequently in the literature (e.g., Walkinshaw 1973, Lewis 1977, Tacha et al. 1985).

The Lesser-Canadian-Greater Sandhill Crane Group exhibits clinal variation in morphological characters, and there are no positive means of distinguishing among them except between the Lesser Sandhill Crane and the Greater Sandhill Crane at the extremes of their ranges (Meine and Archibald 1996). Random pairing among the three subspecies (Lesser-Canadian-Greater Sandhill Cranes) does occur, and hybridization occurs along the limits of their ranges (Tacha et al. 1985). Recent DNA studies affirm that the

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This dissertation follows the style and format of The Auk.

Canadian Sandhill Crane subspecies is intermediate between the Lesser Sandhill Crane and the Greater Sandhill Crane (Petersen et al. 2003, Jones et al. 2005). The population numbers of Lesser and Canadian Sandhill Cranes combined have been estimated at approximately
450,000 (Walter 1995) and Greater Sandhill Cranes at 65-75,000 (Pogson and Lindstedt 1990, Urbanek 1994, Drewien et al. 1995). These migratory subspecies are distributed across a broad breeding range in northern North America and eastern Siberia, with wintering grounds in the southern United States and northern Mexico. The migratory group has been defined as the "Mid-continental Sandhill Cranes" by Tacha (1981).

The other three subspecies (Mississippi Sandhill Cranes, Florida Sandhill Cranes, and Cuban Sandhill Cranes) exist as small, non-migratory populations with restricted ranges in the southern United States (Mississippi, Florida, and southern Georgia) and Cuba (Meine and Archibald 1996). The Mississippi Sandhill Crane was described as a subspecies in 1972, based mainly on color differences between it and the Florida Sandhill Crane (Aldrich 1972). The existing population of Mississippi Sandhill Cranes in Mississippi was probably more widespread in the past, and may have hybridized with Florida Sandhill Crane and Cuban Sandhill Crane to the east (Meine and Archibald 1996). Additionally, recent genetic study shows that Mississippi Sandhill Cranes, Florida Sandhill Cranes, and Cuban Sandhill Cranes are more genetically like that of the migratory Greater Sandhill Cranes (Jones 2003). The non-migratory populations may have originated as non-migratory extensions of migratory populations and reflects the result of partial migration reinforced by natal philopatry (Jones 2003).

Sandhill Cranes are increasing in numbers, although some local populations may be declining (Meine and Archibald 1996). Overall Sandhill Cranes are classified as Lower Risk under the revised World Conservation Union (IUCN) Red List Categories (IUCN 1994). However, the Mississippi and Cuban subspecies are classified as Critically Endangered (IUCN 1994).

Siberian Crane: subspecies and populations

The Siberian Crane (*G. leucogeranus*) is classified as a critically endangered species under the revised IUCN Red List categories (Bird Life International 2000). The species is the third rarest crane species and only exists as two localized populations: the eastern and western. The eastern population contains 2,900–3,000, more than 99% of the world's total population of Siberian Cranes (Meine and Archibald 1996). These birds breed in northeastern Siberia and winter along the middle Yangtze River in China (Fig. 1). The western population, which according to recent counts has only nine birds, winters at a single site along the south coast of the Caspian Sea in Iran and breeds just south of the Ob River east of the Ural Mountains in Russia (Meine and Archibald 1996).

LESSER SANDHILL CRANE AND THE EASTERN POPULATION OF SIBERIAN CRANE

Lesser Sandhill Crane

The average height for Lesser Sandhill Crane is 1.2 m with a wingspan of about 2 m (Tacha et al. 1992). The Lesser Sandhill Crane is the smallest subspecies and it has

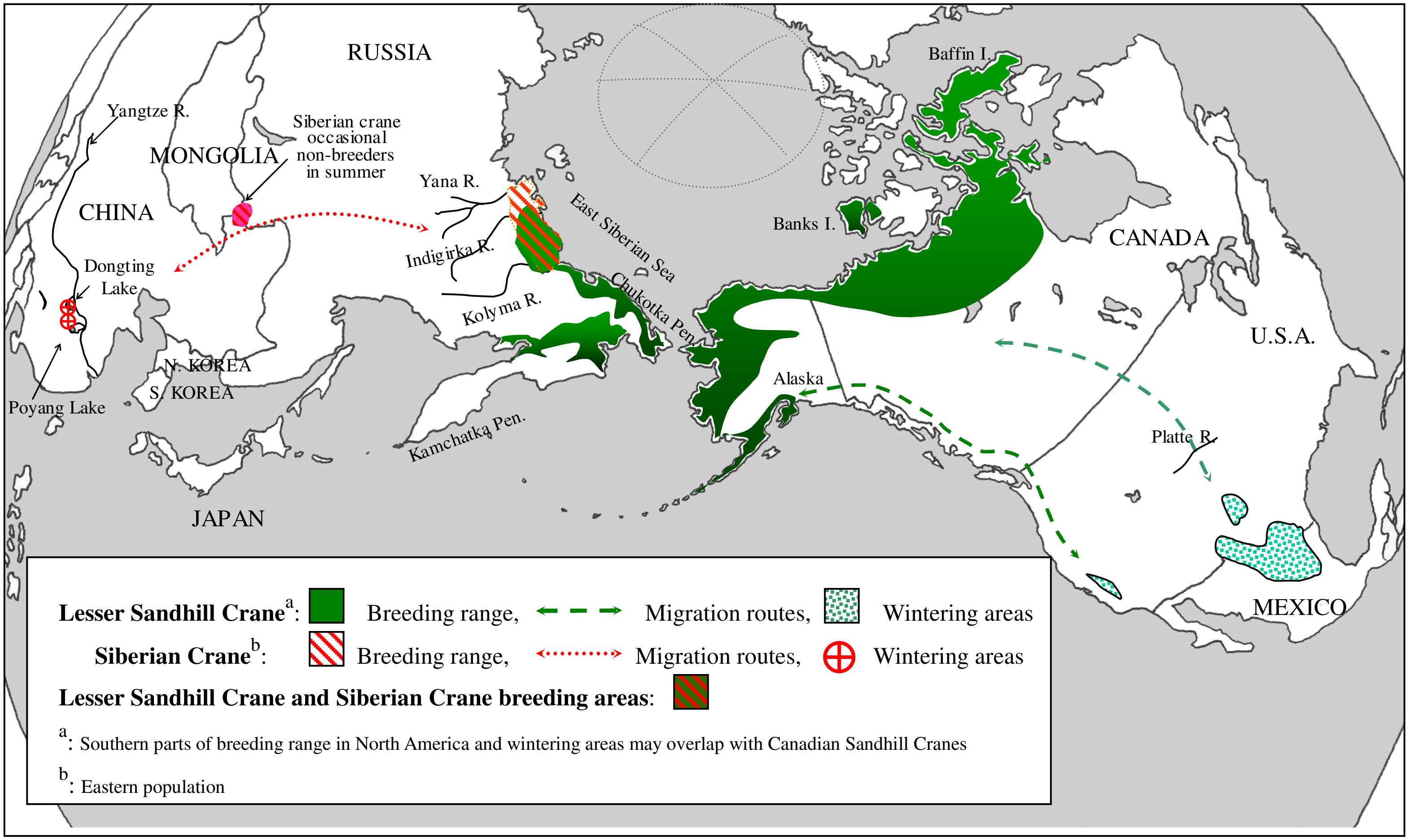


Fig. 1. Distribution of Lesser Sandhill Crane and Siberian Crane.

the shortest bill (seldom over 100 mm in exposed culmen length), the shortest tarsus (seldom over 200 mm), while the bare tibia and the bill from the posterior edge of the nares to the tip also are shorter than other subspecies (Walkinshaw 1973). Sexes are similar in plumage (gray color); males are usually larger than females (3.75 vs. 3.34 kg) (Tacha et al. 1992). In general, the smaller-sized and gray shaded species of cranes nest in smaller and/or forested wetlands (Meine and Archibald 1996). Their small size and plumage color may help these cranes hide while on their nests (Meine and Archibald 1996).

In the mid-continent Lesser Sandhill Crane population, successful reproduction may begin at 5 years of age, but mostly (>75%) occurs in birds less than 8-years old (Tacha et al. 1989). Maximum age in the wild is 19.4 years for a bird from the mid-continent Sandhill Crane population (Tacha et al. 1992).

The breeding range of the Lesser Sandhill Crane extends from the arctic and subarctic regions of North America from Baffin Island to the Yukon Territory; in coastal and interior areas of Alaska; and in northeastern Siberia (Walkinshaw 1973, Krechmer et al. 1978, Labutin and Degtyaryev 1988). In northeastern Russia, the Lesser Sandhill Crane inhabits the subarctic tundra from the Kamchatka Peninsula in the east to the Yana River in the west (Krechmer et al. 1978, Labutin and Degtyaryev 1988) (Fig. 1).

Typical breeding territories in Alaska were in wet marsh or sedge-grass meadow areas, and broods spent the most time in slough banks, heath tundra, and short-grass meadows (Boise 1977). Walkinshaw (1973) reported use of similar habitats in tundra areas of northern Canada. The size of Lesser Sandhill Crane nesting territories varies widely within the subspecies and breeding range (e.g., Drewien 1973, Reed 1988). Reed (1988) found that an average territory size of nesting Lesser Sandhill Cranes in Banks Island, in the Northern Territories, was 130 ha. Conversion to circular buffers resulted in a circle area with 233 m and 643 m radius, respectively.

Nests in wetland sites are built of the dominant vegetation in the nesting area, while dry site nests are minimally prepared (Walkinshaw 1973, Meine and Archibald 1996). Lesser Sandhill Cranes in Alaska construct tall nests in wet marshes and sedge-grass meadows (Boise 1977) and build similar nests in wet, brush-covered tundra up to elevations of 1,000 m in eastern Siberia (Dement'ev and Gladkov 1951). Reed (1988) located Lesser Sandhill Crane nests in extensive sand dune regions on Banks Island. Walkinshaw (1973) described Lesser Sandhill Cranes initiating nest building by late May in western Alaska and early June on Banks Island. Average clutch size in arctic regions was 1.9 eggs per nest (Walkinshaw 1981). The incubation period for Lesser Sandhill Crane is 29–32 days (Drewien 1973). Hatching success is 63.6% and nesting success is 66.7% in the Yukon-Kuskokwim Delta, Alaska (Boise 1977). The earliest Lesser Sandhill Crane chick fledged at 55–56 days in Alaska (Boise 1977). Young cranes in the arctic must grow much faster than those hatched further south, because all cranes leave Banks Island and Siberia by late August or early September when snows begin to cover the land (Walkinshaw 1973).

Foods vary widely depending on what is available in various seasons and locations (Walkinshaw 1949, 1973). The relatively short bills of crane species allow them to forage more efficiently for seeds, insects, and other food items in upland habitats (Meine and Archibald 1996). In Alaska, breeding cranes eat assorted berries, insects, and small mammals (Walkinshaw 1949, Boise 1977). Reed (1988) observed Lesser Sandhill Cranes ate chicks of small birds on Banks Island. Boise (1977) stated that Lesser Sandhill Crane seem to become more carnivorous during summer although largely granivorous during fall and winter. Diets during migration and wintering are mostly cultivated grains (Tacha et al. 1994). Harvested grain fields (corn, wheat, and barley) were the principal habitat types used by Lesser Sandhill Cranes during spring migration in Nebraska, Saskatchewan, and Alaska, respectively (Iverson et al. 1987). Wheat, corn, sorghum, and milo are major food items whenever available on the wintering grounds (Tacha et al. 1992).

The earliest Lesser Sandhill Cranes arrived at their breeding ground in Eastern Siberia in early May (Krechmer et al. 1978), then left by late August or early September, crossing to western Alaska from Siberia to the Canadian mainland (Walkinshaw 1981). The main part of the population (about 80%) winters in the seasonal playa lakes, riparian wetlands, irrigated pastures, croplands, and grain fields of eastern New Mexico, northwestern Texas, and central northern Mexico (Iverson et al. 1985, Tacha et al. 1992, Drewien et al. 1996, Chavez-Ramirez 2005) (Fig. 1). Large migratory flocks of Lesser Sandhill Cranes congregate on the Platte River, Nebraska in the spring, along with most of the Canadian Sandhill Crane population and smaller numbers of Greater Sandhill Cranes (Tacha et al. 1992). A smaller portion of the flock, mainly from southeastern Alaska, migrates through Washington and Oregon and winters in California’s Central Valley (Littlefield and Thompson 1979, 1982; Mickelson 1987) (Fig. 1).

The Eastern Population of Siberian Crane

The Siberian Crane height averages 1.4 m, and the Siberian Cranes are taller than Lesser Sandhill Cranes (Del-Hoyo et al. 1996). The average exposed culmen length for males is 188 mm, while for females it is 178 mm (Johnsgard 1983). The average tarsus length for males is 264 mm, while it is 259 mm for females (Johnsgard 1983). The average summer weight is 6.39 kg for males and 5.48 kg for females (Johnsgard 1983). The plumage is pure white, except for the primaries, primary coverts, and alula, which are black (Johnsgard 1983). In general, the larger-sized and white-colored species of cranes dwell in vast open wetlands (Meine and Archibald 1996). Their size and bright white plumage makes these cranes conspicuous to conspecifics, and presumably facilitates defense of breeding territories (Meine and Archibald 1996).

Siberian Cranes reach full maturity when they are 7-years old, but they may form pairs and breed when only 3-years old (N. I. Germogenov pers. comm., Yakutsk Institute of Biology). Maximum age in the wild is unknown.

The main breeding grounds of the eastern population of Siberian Crane covers 82,000 km^2 in the Yakutia region of northeastern Siberia, south of the East Siberian Sea between the Yana and Kolyma Rivers (Flint and Sorokin 1982, Labutin et al. 1982, Degtyaryev and Labutin 1991) (Fig. 1). Non-breeding individuals range widely, and have occasionally been observed during the breeding season in the Russia-Mongolia-China border region (Meine and Archibald 1996) (Fig. 1).

The Siberian Crane's distinctive morphology, vocalizations, and feeding and courtship behavior distinguish it from the other *Grus* species (Johnsgard 1983, Sauey 1985). It also is the most specialized in terms of its habitat requirements, exclusively using wetlands for nesting, feeding, and roosting (Meine and Archibald 1996). Siberian Cranes are most frequently observed wading and probing for food in shallow (up to 30 cm) water (Meine and Archibald 1996). The Eastern population's breeding grounds in Yakutia are in low-arctic tundra (moss-lichen tundra and grass-sedge-dominated wetlands), more rarely in forest-tundra transitional areas, and sometimes in the northernmost taiga between the Arctic Ocean and uplands to the south (Flint and Kistchinski 1981).

Nests of Siberian Cranes are scattered within the breeding ranges, and reflect a preference for wide expanses of fresh water with good visibility (Meine and Archibald 1996). Densities of nesting Siberian Cranes have been based on an aerial census in the literature (Flint and Kistchinski 1981, Flint and Sorokin 1981, Germogenov 1998), but actual territory sizes were uncertain. Home ranges of nesting Siberian Cranes have not been recorded; however, Siberian Cranes with chicks have been observed at maximum 2,000 m from their nests (N. N. Egorov per. comm., Yakutsk Institute of Biology).

Nests consist of flat mounds of grass and sedge elevated 12–15 cm above the surrounding water (Meine and Archibald 1996). Eggs are generally laid from late May to mid-June, with peak production occurring in the first week of June (Meine and Archibald 1996). In most cases, two eggs are laid, with only one chick surviving to fledging (Meine and Archibald 1996). The incubation period is about 29 days, and chicks fledge at 70–75 days (Meine and Archibald 1996).

The Siberian Crane, the most aquatic of all cranes, has the longest bill and toes among other *Grus* species (Meine and Archibald 1996). These physical characteristics are related to adaptations for probing and walking in mud (Meine and Archibald 1996). The diet of Siberian Cranes on the breeding grounds consists of plants, including roots, rhizomes, sprouts of sedges, seeds, and berries, as well as insects, fish, frogs, small mammals (e.g., voles and lemmings), and other small aquatic animals (on occasion, including chicks of waterfowl) (Meine and Archibald 1996). Animal foods are especially important at the beginning of the breeding season, when plant foods are unavailable, and during the chick-rearing period (Sauey 1985). Along migration routes and on the wintering grounds, Siberian Cranes eat primarily roots, bulbs, tubers, rhizomes, sprouts, and stems of aquatic plants (especially sedge tubers), but also forage on clams, fish, snails, and other aquatic animals, if they are available (Meine and Archibald 1996). In China, cranes of the Eastern population feed primarily on pondweed (*Potamogeton malainus*), stems and tubers of wild celery (*Vallisneria spiralis*), and small freshwater clams (Liu and Chen 1991).

The arrival of the Siberian Cranes on the nesting grounds in Eastern Siberia takes place during the last 10 days of May, when the tundra is still mostly covered with snow (Perfilyev 1965). Siberian Cranes start their migration from the breeding grounds between the middle of September to early October, dependent upon daytime temperatures dropping to about –5 ^{o}C (Kanai et al. 2002). The population migrates more than 5,000 km following the Yana, Indigirka, and Kolyma River valleys, and then into eastern China, with several resting areas and longer-term stopover sites (Degtyaryev and

Labutin 1991, Harris 1992, Kanai et al. 2002) (Fig. 1). The population winters in a limited number of wetlands along the middle Yangtze River in south-central China (Ding and Zhou 1991). Approximately 98% of the population winters in one area at Poyang Lake in northern Jiangxi Province (Meine and Archibald 1996). The Poyang Lake Nature Reserve protects some of the most important wintering sites in this area, but the birds also use adjacent sites outside the reserve (Meine and Archibald 1996). The remainder of the known population, perhaps a hundred or more birds, winters at Dongting Lake in the city of Yueyang in Hunan Province (Gui 1991, Harris 1991).

JUSTIFICATION

All bird species are restricted, to varying degrees, in the range of habitats they occupy (Wiens 1989). By definition, the members of a local community share at least portions of their geographic distributions, but within local or regional landscapes, some species disappear and other species appear (Wiens 1989). Classical competition theory dictates that ecologically identical species cannot coexist (Wiens 1989).

In the 1950's (Dement'ev and Gladkov 1951), the population of the Lesser Sandhill Crane in eastern Siberia inhabited a smaller geographic distribution compared to present day. In the 1970's, the population of the Lesser Sandhill Crane covered practically all the arctic tundra from far eastern Russia to west of the Kolyma River (Kishchinsky 1980, Labutin and Degtyarev 1988). During the past two decades, populations of the Lesser Sandhill Crane in eastern Siberia increased and expanded westward (N. I. Germogenov pers. comm., Yakutsk Institute of Biology). The Lesser Sandhill Crane population between the Kolyma River and the west side of the Indigirka River has existed sympatrically with the Siberian Crane for the last two decades (Fig. 1).

Observations of Lesser Sandhill Cranes on their breeding grounds in North America have been reported by numerous authors, including Conover (1926), Brandt (1943), Walkinshaw and Stophlet (1949), Gabrielson and Lincoln (1959), and Walkinshaw (1965*a*). Convover (1929) and Brandt (1943) briefly described breeding habitat types, breeding behaviors, nest structures, and shapes and colors of Lesser Sandhill Crane eggs on Hooper Bay, Alaska. Walkinshaw and Stophlet (1949) found nests of Lesser Sandhill Cranes at Johnson River, Alaska in 1946, described nest sizes, and surrounding vegetation types. Gabrielson and Lincoln (1959) described breeding ranges of Lesser Sandhill Cranes in Alaska, while Walkinshaw (1965*a*) observed Lesser Sandhill Cranes during his brief visit to Banks Island and indicated that the island may consist of several distinct Lesser Sandhill Crane breeding populations, each adapted to different environmental conditions.

Lesser Sandhill Cranes in Siberia have been reported by Dement'ev and Gladkov (1951), Krechmer et al. (1978), Kishchinsky (1980), Labutin and Degtyaryev (1988). Dement'ev and Gladkov (1951) described physical appearances and distributions of Lesser Sandhill Cranes in Siberia. In addition, Krechmer et al. (1978), Kishchinsky (1980), and Labutin and Degtyaryev (1988), described Lesser Sandhill Cranes in Siberia as part of natural history accounts, but their studies were restricted to a few days of observations.

Comprehensive studies of the breeding biology of Lesser Sandhill Cranes have been conducted in Alaska and Banks Island (e.g., Boise 1977, Reed 1988). Boise (1977) studied the breeding biology, including distribution, density, and descriptive breeding habitats on the Yukon-Kuskokwim Delta, in Alaska. Similarly, Reed (1988) reported breeding biology, including distribution, density, and descriptive behavioral activities, of the Lesser Sandhill Cranes on Banks Island.

Studies of Siberian Cranes in Eastern Siberia have been reported by Flint and Kistchinski (1981), Flint and Sorokin (1982), Labutin et al. (1982), Degtyaryev and Labutin (1991), and Germogenov (1998). Flint and Kistchinski (1981) described the general breeding biology of Siberian Cranes in Yakutia including their population sizes and descriptive behaviors. Flint and Sorokin (1982), Labutin et al. (1982) Degtyaryev and Labutin (1991), and Germogenov (1998) focused on Siberian Crane population sizes based on aerial censuses and large-scale descriptions of their breeding grounds.

Unfortunately, the relationship between the abundant Lesser Sandhill Cranes and endangered Siberian Cranes has not been adequately studied. In order to evaluate the existing relationships between Lesser Sandhill and Siberian cranes, comparative nest site characteristics, habitat-use patterns, food abundance, and behavioral patterns should be examined in areas of distribution overlap.

The spatial patterns of animal and plant distributions provide important insights into the dynamics of populations and ecological interactions (Davis et al. 2000). To understand habitat characteristics of Lesser Sandhill Cranes, Siberian Cranes, and the spatial relationships between these two species, a landscape analysis of their breeding habitats is required in the overlapped breeding regions. Food abundance and habitat-use patterns of Lesser Sandhill and Siberian cranes in the Siberian tundra also have not been studied.

Studying animal behavior is one crucial approach used to understand a species (Dilger 1962). Drickamer and Vessey (1992) defined the study of animal behavior as a method to examine relationships between animals and their environment, in order to preserve and maintain the environment, and to conserve and protect endangered species. The crane's behavior reflects its many survival strategies and adaptations. Cranes are often used as indicators of ecosystem health in wetlands because they mate for life, exhibit fidelity to nesting territories, and defend territories against conspecifics (Walkinshaw 1989).

The behavior of Sandhill Cranes has been studied and discussed in several publications (e.g., Walkinshaw 1949, 1973; Littlefield 1968, Drewien 1973, Voss 1976, Tacha 1981, 1987, 1988; Tacha et al. 1987). Littlefield (1968) and Drewien (1973) described comprehensive behavioral activities and discussed social organization of Greater Sandhill Cranes. Voss (1976) described and provided lists of behavioral activities (ethogram) of Greater Sandhill Cranes. Tacha (1981, 1987, 1988) and Tacha et al. (1987) documented frequency, duration, and time allocated to various behaviors by mid-continent Sandhill Cranes during migration and wintering periods. Biological studies of Lesser Sandhill Cranes were conducted by Boise (1977) in Alaska, and Reed (1988) on Banks Island; however, time activity budgets of Lesser Sandhill Cranes were not discussed.

Sauey (1976, 1985) described behaviors of Siberian Cranes on the wintering grounds as a part of his comprehensive Siberian Crane studies. Flint and Kistchinski (1981) generally described behaviors of Siberian Cranes on the Siberian tundra, although time activity budgets of the cranes were not discussed.

To gain knowledge of the Lesser Sandhill and Siberian cranes, behavioral observations are important to understand not only the species itself but also their roles in Siberian tundra ecosystems. Observational studies of Lesser Sandhill and Siberian cranes on the breeding grounds on the Siberian tundra have never been conducted and compared.

Due to the growing population of Lesser Sandhill Cranes in this area, nesting territories of Lesser Sandhill and Siberian cranes may overlap (N. I. Germogenov pers. comm., Yakutsk Institute of Biology). Significant overlap in food and habitat niche dimensions between the two species occurs, and may lead to severe competition between these two species. High levels of heterospecific competition may lead to the gradual disappearance of one of the species (Lack 1947, 1971). Intense competition between the two species could have serious conservation implications. In order to coexist the Lesser Sandhill and Siberian cranes should differ in some essential ways of exploiting different resources or use the same resources in different ways in the Siberian tundra. It will be important to determine whether Lesser Sandhill and Siberian Cranes are competing for resources or use different resources while on the Siberian tundra.

The study of comparative breeding ecology of Lesser Sandhill Cranes and the endangered Siberian Cranes on the breeding habitat may contribute further to conservation efforts and improve management for these two species in Eastern Siberia.

OBJECTIVES

The main objective of this study was to compare dispersion patterns and resource use of breeding Lesser Sandhill and Siberian cranes in areas of sympatry. Specific objectives of this study and predictions were:

I. To characterize and compare nest sites of Lesser Sandhill and Siberian cranes using spatial analysis.

- Within the study area, a mean area (ha) per Lesser Sandhill Crane nest will be smaller than mean area (ha) per Siberian Crane nest.
- Distances (m) between heterospecific nests will be closer than distances to conspecific nests.
- Siberian Cranes will require open water areas for their nest sites than Lesser Sandhill Cranes.
- Siberian Crane nest areas will be in wet areas at higher water levels, taller vegetation, and less vegetation cover than Lesser Sandhill Crane nest areas.
- Lesser Sandhill Crane nest areas will be in dryer areas with lower water levels, shorter vegetation, and more vegetation cover than Siberian Crane nest areas.

II. To determine and compare habitat-use patterns of the Lesser Sandhill and Siberian cranes in relation to food abundance in different vegetation types.

- It is expected Lesser Sandhill Cranes will use drier areas more frequently, where terrestrial foods may be more abundant.
- Lesser Sandhill Cranes will use wet areas to a greater extent when terrestrial foods

are not available on partially frozen ground in June.

- It is expected Siberian Cranes will use wet areas more frequently, where aquatic foods will be abundant.

III. To determine and compare time activity budgets between Lesser Sandhill and Siberian cranes, and between different months for each species.

- Both species of cranes will spend most of their time in locomotion, foraging, and alert.
- Both species of cranes will spend more time in alert behaviors during incubation period in June for nest protections.
- Both species of cranes will spend more time in locomotion and less time alert toward late July.

CHAPTER II

STUDY AREA

The study area was located within the Kytalyk Resource Reserve (1,607,000 ha) in the Khroma and Indigirka River Delta in the Republic of Sakha (Yakutia) (Fig. 2). The study area encompassed about 30,000 ha (centered on 70^{o} 50' north latitude and 147^{o} 30' east longitude) on the southeastern side of the Reserve, and was located about 30 km north of the village of Chokurdakh and about 100 km inland from the East Siberian Sea. Snow cover completely thaws between the end of May and the beginning of June in the region (Shmatkova and Klokov 2001). Interior tundra and wetlands of the Indigirka River Delta were typically free of ice by mid-June, and river channels broke by 20 June (Pearce et al. 1998*a*). Summer temperatures ranged from - 4^{o} to 22 ^{o}C, with an average of 5 ^{o}C (Pearce et al. 1998*b*). Continuous daylight occurred from the end of May to early September (Wagner et al. 2003). Mean annual precipitation in the region is about 250 mm (Shmatkova and Klokov 2001).

Referring to descriptions by Bliss (1981), the study area is categorized as low-arctic tundra. The low-arctic tundra encompasses Alaska, mainland Canada and southern Baffin Island and extends to 74 ^{o} north latitude in western Greenland (Bliss 1981). The Indigirka River Delta lies within the southern sub-zone of the low-arctic tundra biome, which occurs from the Lena River Delta to the eastern edge of Chukotka Peninsula (Treshnikov 1985, Stishov et al. 1989, Pearce et al. 1998*b*).

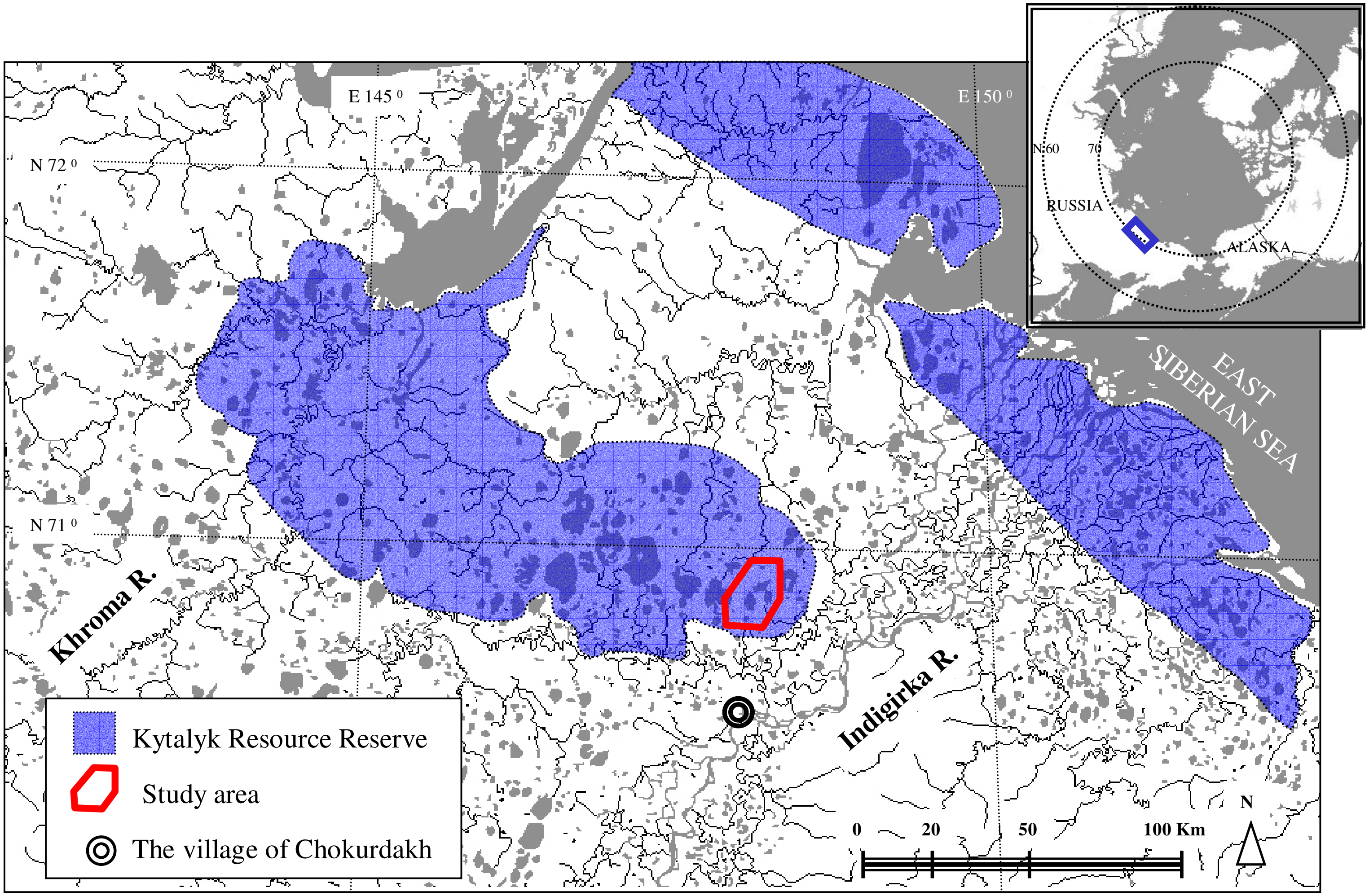


Fig. 2. Kytalyk Resource Reserve and the study area in Eastern Siberia.

The study area consists of polygonal tundra and several large drained-basin complexes, which are characterized by deep (>1 m) lakes and ponds, often containing numerous small islands (<9 m^2) (Bergman et al. 1977, Pearce et al. 1998*b*) (Fig. 3). Ice wedges are bodies of underground ice that originate from contraction cracking of frozen soils during extreme low winter temperatures in arctic tundra (Milner et al. 1997). The eventual result is a series of intersecting cracks, polygonal in shape, into which blows snow resulting in melt-water accumulation during winter and spring (Milner et al. 1997). Because cracks extend into the permafrost, entering water turns to ice and expands (Milner et al. 1997). Through repeated winter cracking, ice wedges increase in width and may reach up to 10 m (Billings and Peterson 1980). These ice wedges in the underlying permafrost result in extensive areas of the tundra being characterized by polygonal networks of troughs and ridges (Milner et al. 1997).

The cryogenic formation of pingos also is widespread in permafrost areas (Guseva 2000). Pingos occur in the tundra when underground water freezes and expands, forcing terrain upward (Arritt 1993). Yearly, as the ponds thawed and then froze, hills "grew" taller (Guseva 2000). Polygon ridges and pingos often rose several meters above surrounding wet tundra, creating more xeric vegetative communities (Pearce et al. 1998*b*).

This southern sub-zone of the low-arctic tundra area has a vascular plant flora of over 200 vascular plant species and 70 lichen species, approximately 100 moss species, and 300 algae taxons (Shmatkova and Klokov 2001). Mosses cover the ground in most areas, typically forming peat 10- to 30-cm thick (Bliss 1981). Other plants characteristic

Fig. 3. View from helicopter over one portion of the study area in the Kytalyk Resource Reserve in July 2000.

of arctic polygonal tundra includes sedges (*Carex* spp.), cotton grasses (*Eriophrum* spp.), bluegrasses (*Poa* spp.), and dwarf willows (*Salix* spp.) (Uspenskii et al. 1962, Matveev 1989).

Mosquitoes are the most noticeable arthropods in the arctic tundra during summer periods (Seton 1981). Several species of beetles, caterpillars or cocoons, flies, and spiders are found in the area (N. I. Germogenov pers. comm., Yakutsk Institute of Biology).

The Kytalyk Resource Reserve also is inhabited by over 130 vertebrate species, of which 13 bird species and two mammalian species are listed in the Red Book of the IUCN (Ministry of Environmental Protection of the Sakha Republic 1998).

Mammals are represented by tundra and northern-boreal species (Shmatkova and Klokov 2001) with the reindeer (*Rangifer tarandus*) as the most characteristic mammals, over-wintering in the open woodland and forest tundra, then migrating to coastal tundra to calve and for summer grazing (Bliss 1981, Shmatkova and Klokov 2001). Other characteristic common mammals in the area are arctic fox (*Alopex lagopus*), ermine (*Mustela erminea*), Siberian lemming (*Lemmus sibiricus*), collared lemming (*Dicrostonyx torquatus*), Middendorf's vole (*D. torquatus*), narrow-skulled vole (*Microtus gregalis*), root vole (*M. oeconomus*) and least weasel (*Mustela nivalis*) (Shmatkova and Klokov 2001).

Broad whitefish (*Coregonus nasus*), muksun (*C. muksun*), peled (*C. peled*), and Siberian cisco (*C. sardinella*) are commonly seen in rivers and lakes (Shmatkova and Klokov 2001). Ninespine stickleback (*Pungitius pungitius*) is the most abundant fish in shallow water and pools in the reserve (N. I. Germogenov pers. comm., Yakutsk Institute of Biology).

These tundra regions have numerous species of birds that migrate along Nearctic and Palearctic flyways to breed (Pearce et al. 1998*b*). The study area and its surroundings host between 40 and 60 breeding species of migratory birds each summer (Pearce et al., 1998*b*). Besides Lesser Sandhill and Siberian cranes, other characteristic birds for this region are Steller's Eider (*Polysticta stelleri*), Spectacled Eiders (*Somateria fischeri*), Red-throated Loon (*Gavia stellata*), Black Brant (*Branta bernicla*), Curlew Sandpiper (*Calidris ferruginea*), Sharp-tailed Sandpiper (*C. acuminata*), Broad-billed Sandpiper (*Limicola falcinellus*), Ross' gull (*Rhodostethia rosea*), Ruff (*Philomachus pugnax*), Willow Ptarmigan (*Lagopus lagopus*), and Snow Bunting (*Plectrophenax nivalis*) (Pearce et al. 1998*a*,*b*). Rare falcons such as Peregrine Falcon (*Falco peregrinus*) and Gyrfalcon (*F. rusticolus*) also breed in this area (Shmatkova and Klokov 2001).

The Kytalyk Resource Reserve was established in 1996 to ensure protection of the eastern population of endangered Siberian Crane (Nikiforov 1996). More than 380 Siberian Cranes (about 12.7% of the eastern population) were recorded during the breeding season in the reserve in 1996 (Germogenov 1998). A portion of the Kytalyk Resource Reserve was chosen as the study area because Lesser Sandhill and Siberian cranes were sympatric there.

CHAPTER III

METHODS

Research was performed from late May to early August 2000 within the 30,032 ha of tundra surrounding the research main camp (70° 50' north latitude and 147° 30' east longitude) (Chapter II, Fig. 2).

CHARACTERIZATION OF NESTING SITE USING SPATIAL ANALYSIS

Characterization of study area for spatial analysis

The study area was categorized into four discrete areas based on their geological appearances. The four areas were; (1) upland, (2) moderate-wet, (3) wet, and (4) open-water (Fig. 4). In addition, the study area was subdivided into six landscape types (high hills, low hills, polygons, high basins, low basins, and lakes) for closer evaluations in the study area (Fig. 4). Classifications of the four major areas and six subdivided landscape types were as follows:

(1) Upland area. Moisture conditions on upland areas were estimated subjectively as dry to touch. I subdivided the upland area into "high hills" and "low hills" (Fig. 4). High hills include pingos formed at higher elevation (≥20 m above sea level) in this study. Low hills were densely covered with hummocks, and estimated subjectively as flat dry areas of low elevation (<20 m above sea level and above surrounding water level). Low hills were formed between high hills and wide rim edges of polygon areas.

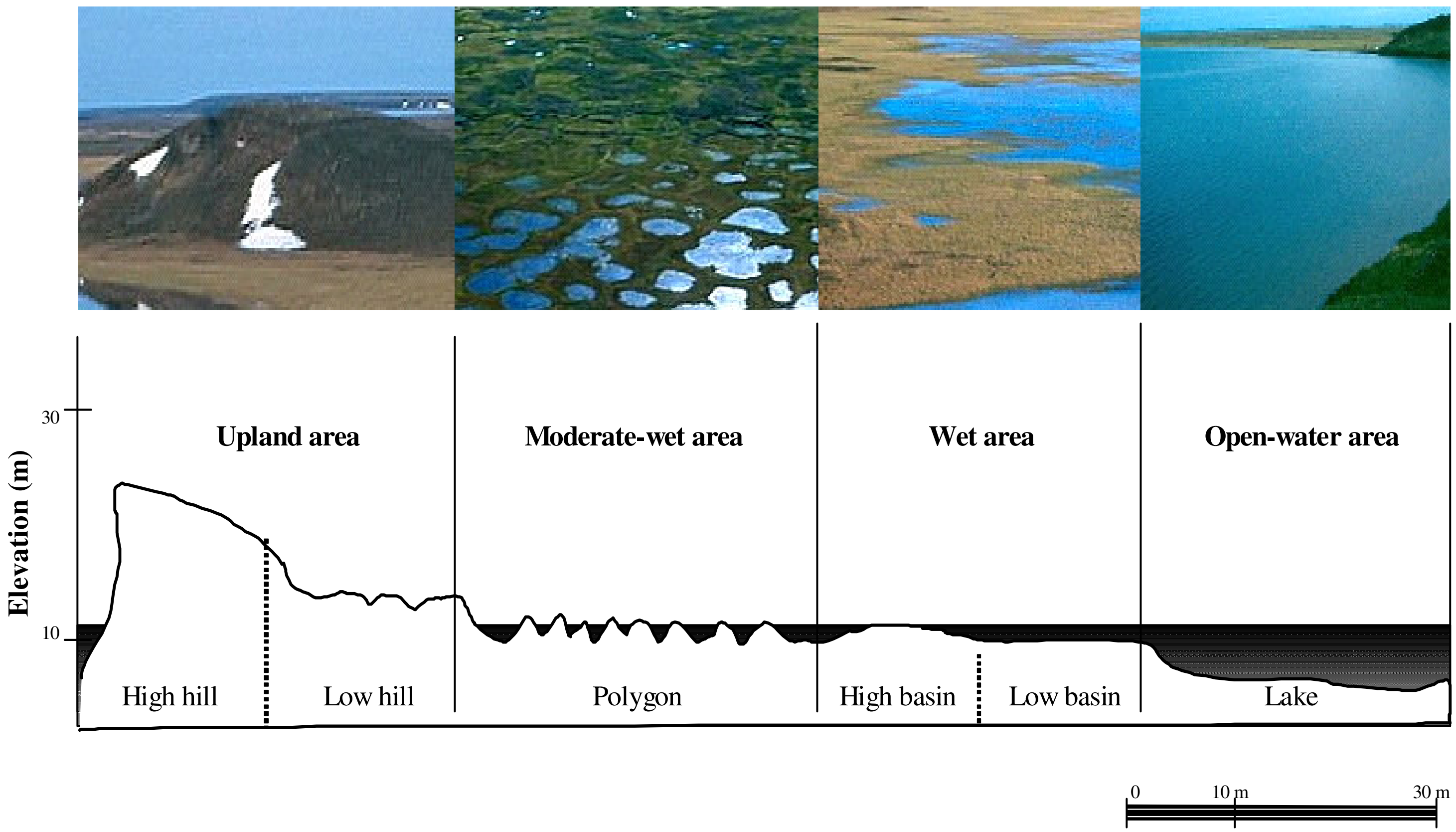


Fig. 4. Landscape profile showing the four different areas (upland, moderate-wet, wet, and open-water) and the six subdivided landscape types (high hill, low hill, polygon, high basin, low basin, and lake). Note: the intent of this figure is to visually illustrate the different landscape types; it is not a real representation of any actual portion of the study area.

(2) Moderate-wet areas. Moisture conditions of moderate-wet areas were estimated subjectively as moist to touch. The moderate-wet areas were considered transitional areas between upland-dry and wet areas in this study (Fig. 4). Moderate-wet areas were about the same elevation of surrounding water level and also known as a landscape type, “polygon”. Two related types of polygons typically occurred, depending on the state of the ice wedges: low-centered polygons from above active ice wedges that were saucer-shaped depressions surrounded by a raised rim on either side of the ice wedge; and high-centered polygons resulting when the ice wedged under low-centered polygons melt, leaving depressions where there once were ridges (Svensson 1963, Milner et al. 1997). Due to difficulty of classifying between low and high polygons on the map and from ground surveys, I categorized high and low polygons as one type, moderate-wet (polygon) area in this study.

(3) Wet areas. Wet areas were widely flooded areas that included “high basins” and “low basins” (Fig. 4). Moisture conditions of wet areas were estimated subjectively as wet (lower elevation than surrounding water level) and were forming pools (Markon and Derksen 1994). I categorize “high basins” as flat moist areas with standing water in pools from 1 cm to 5 cm in depths. Low basins were categorized as wet areas with standing water in more than 5 cm in depth in this study.

(4) Open-water areas. Open-water areas included lakes and ponds (Fig. 4). A 1:100,000-scaled contour map, ground surveys, and photographic images from a helicopter were used to identify these four different areas and six subdivided landscape types. Composition and distribution of different landscape areas (ha) in the study area

were measured using a Geographic Information System (GIS) program (ArcView 8.1).

Nest searches

Nest searches were conducted during late May to early July 2000 to locate nests of Lesser Sandhill and Siberian cranes within the study area. Ground searches were conducted every day except during harsh weather conditions (snow storms, heavy rains and/or thick fogs). To locate crane nests, activities of cranes were closely monitored from high hills with the aid of 8 X binoculars or a 20 X–60 X spotting scope, and cranes were followed by tracking to nests. When nests were located, their exact locations were confirmed by ground searches. Nest sites were marked on a 1:100,000-scaled contour line map.

Mean distances and mean area of crane nests

Distances (m) between nests and mean areas (ha) of each species' nests were determined on maps using Arc View 8.1. The shortest distances from each crane nest to conspecific crane nests were measured, and then the mean area per Lesser Sandhill Crane nest and the mean area per Siberian Cranes nest were calculated to be circular in area [π (the mean distance / 2 $)^2$]. I made the assumption that minimum area estimated represents the buffer area of separation between nests within same species.

The shortest distances from each crane nest to heterospecific crane nests also were measured. Mann-Whitney *U* tests were used to compare the shortest distances to conspecific and heterospecific crane nests.

Landscape composition at various distances around nests

Arc View 8.1 was used for spatial analysis of landscape composition at various distances around nests of Lesser Sandhill and Siberian cranes. Various radius buffer areas (Baker et al. 1995) from each Lesser Sandhill Crane nest, Siberian Crane nest, and random point were created with GIS to compare landscape composition of breeding areas of these two species at various distances.

To cover possible crane activity ranges of both species, buffer sizes of 200 m, 400 m, 600 m, 800 m, 1,000 m, 1,200 m, 1,400 m, 1,600 m, 1,800 m, and 2,000 m radius from each Lesser Sandhill Crane nest, Siberian Crane nest, and random point were created with Arc View 8.1 (Fig. 5).

Random points were automatically selected by the GIS program for comparison as control points. Random points were chosen in available landscape types within the study area, except lakes. Lakes were excluded for selection because open water areas were not suitable for nesting (Walkinshaw 1965*b*).

Areas (ha) of the six landscape types (high hills, low hills, polygons, high basins, low basins, and lakes) within each buffer area were compared with the same buffer area of Lesser Sandhill Crane nests, Siberian Crane nests, and random points. A Two-Factor Analysis of Variance test was used to determine how distributions of landscape type differed for Lesser Sandhill Crane nests, Siberian Crane nests, and random points.

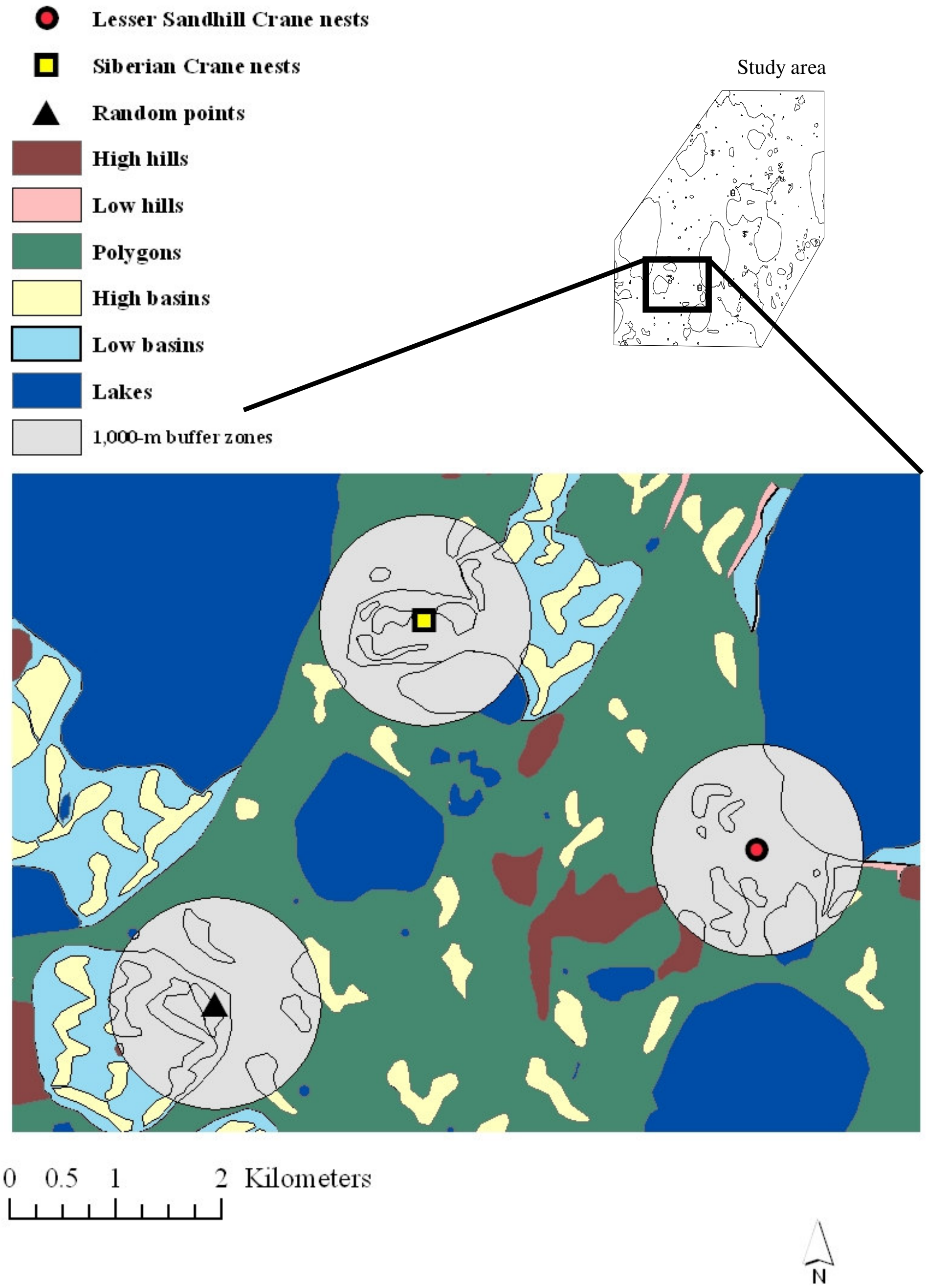


Fig. 5. Example of buffer areas. Buffer areas from each Lesser Sandhill Crane nest, Siberian Crane nest, and random point to 1,000m radius zones were created for comparisons.

Microhabitat evaluations of crane nest sites

Ground surveys for microhabitat evaluations around crane nest sites were conducted in early July 2000 within the study area. Vegetation data were taken using a frame quadrat method (Bullock 1996). Water depth (cm), vegetation height (cm), and vegetation cover (%) were collected at each 0.25 m x 0.25 m quadrat plot around each crane nest site.

A total of 30 plots was sampled for water depth, vegetation height, and vegetation cover around a 50 m radius from each nest site. Five plots at 10-m intervals at 90-degree compass directions from the nest were sampled. The direction of the first, relative to the center, was random and each subsequent subplot was 90 degrees from the one preceding it. In addition, 10 plots along the four axes were randomly sampled at each nest area.

To compare nest site characteristics, random plots also were sampled as control sites. Water depth, vegetation height, and vegetation cover were collected at each random plot, which was sampled every 100 m between research sites while walking from one crane nest to another crane nest in the study area.

While conducting quadrat plot sampling at crane nest sites and random sites, ground cover (%) of each vegetation group also was recorded. The major plant species in the study area was categorized to five different physiognomic groups based on their appearances: *Carex* spp, Moss, Tussocks, Forbs, and Shrubs. Identification of plant species of arctic tundra in Siberia followed Tikhomirov et al. (1969) while the five different categories of vegetation types used follow Hupp and Robertson (1998). The Moss type included lichens and sponge type mats. Tussocks were hummocks of grasses bound together by their roots. Forbs were small, upright soft-stemmed or non-woody plants with broad-leaves including the growth-form of many common wildflowers. Shrubs were short woody plants, such as *Salix* spp. Flint and Kistchinski (1981) reported that Siberian Cranes feed mainly on the roots, rhizomes, and sprouts of sedges (*Carex* spp.) in tundra. *Carex* spp. may be one of the indicator species of Siberian Crane breeding habitat in the tundra. As a result, I categorized *Carex* spp. as one vegetation type in this study.

A Kruskal-Wallis test was used to compare means of water depth, vegetation height, and ground cover of three different locations (Lesser Sandhill Crane nest areas, Siberian Crane nest areas, and random sites). *Post hoc* Mann-Whitney *U* tests were used to evaluate differences of means of each water depth, vegetation height, and vegetation cover between two crane species nest areas, between Lesser Sandhill Crane nest areas and random sites, and between Siberian Crane nest areas and random sites.

Means of vegetation cover (%) of each vegetation type within a 0.25 m x 0.25 m quadrat plot were compared with the three different locations by a Kruskal-Wallis test. *Post hoc* Mann-Whitney *U* tests were used to evaluate differences of vegetation cover mean (%) of individual vegetation type between two crane species nest areas, between Lesser Sandhill Crane nest areas and random sites, and between Siberian Crane nest areas and random sites.

HABITAT USE PATTERNS IN RELATION TO FOOD ABUNDANCE AND MICROHABITAT EVALUATION

Habitat use patterns of Lesser Sandhill Cranes and Siberian Cranes

Habitat-use patterns were evaluated every day from beginning of June to end of July in 2000 except during harsh weather (snow storms, heavy rains and/or thick fog) conditions. Observation periods varied from 30 min to 6 hours depending on the weather condition of the day. To locate individual Lesser Sandhill and Siberian cranes, crane surveys were conducted from hills, where I could observe entire landscapes over 5 km away with the aid of 8 X binoculars or a 20 X – 60 X spotting scope. Additional crane location data also were collected during nest searches, microhabitat surveys, and behavioral observations.

Three potential habitat areas were identified as upland, moderate-wet, and wet areas (Fig. 4). Data were recorded at each location where a crane was foraging or standing for more than 5 consecutive min. Numbers of days of Lesser Sandhill and Siberian cranes occurrences in each area (upland, moderate-wet, and wet areas) were recorded. Frequencies of days of Lesser Sandhill and Siberian cranes observed in each area were compared. Monthly-habitat-use patterns for each species also were compared.

Microhabitat evaluations of upland, moderate-wet, and wet areas

Ground surveys for microhabitat evaluations of upland, moderate-wet, and wet areas were conducted from late June–early July 2000 within the study area. Cluster sampling methods (Greenwood 1996) and frame quadrat methods (Bullock 1996) were used for data corrections. Three 100 m x 100-m areas were randomly selected in each upland, moderate-wet, and wet area, with 10-m intervals established on two sides of a 100 m x 100-m area. Stakes were placed at each 10-m interval point on the two sides and numbered from 0 to 10. On each side, a random number was selected. At the point, where two random numbered coordinates intercepted, a (0.25 m x 0.25-m quadrat) plot was located and sampled. Thirty (0.25 m x 0.25-m quadrat) plots were sampled in each 100 m x 100-m area. This provided a total of 90 (0.25 m x 0.25-m quadrat) plots for each upland, moderate-wet, and wet area. Water depth (cm), vegetation height (cm), and vegetation cover (%) were collected at each (0.25 m x 0.25-m quadrat) plot.

Ground cover (%) of each vegetation group was also measured similar to crane nest sites and random sites during 0.25 m x 0.25-m quadrat plot sampling on upland, moderate-wet, and wet areas. The major plant species in the study area were categorized to five different physiognomic groups based on their appearances: *Carex* spp, Moss, Tussocks, Forbs, and Shrubs. Identification of plant species of arctic tundra in Siberia followed Tikhomirov et al. (1969) while the five different categories of vegetation groups used followed Hupp and Robertson (1998). The Moss group included lichens and sponge type mats. Tussocks were hummocks of grasses bound together by their roots. Forbs were small, upright soft-stemmed or non-woody plants with broad-leaves including the growth-form of many common wildflowers. Shrubs were short woody plants, such as *Salix* spp. Flint and Kistchinski (1981) reported that Siberian Cranes feed mainly on the roots, rhizomes, and sprouts of sedges (*Carex* spp.) in tundra. *Carex* spp. may be one of the indicator species of Siberian Crane breeding habitat in the tundra. I categorized *Carex* spp. as one vegetation group in this study.

A Kruskal-Wallis test was used to compare means of water depth, vegetation height, and vegetation cover among three different areas (upland, moderate-wet, and wet areas). *Post hoc* Mann-Whitney *U* tests were performed to reveal differences of each variable among the three areas. Means of vegetation cover (%) of each vegetation type within a 0.25 m x 0.25-m quadrat plot also were compared among the three different locations with the same statistical approach (e.g., Kruskal-Wallis test, *Post hoc* Mann-Whitney *U* test).

Food abundance in upland, moderate-wet, and wet areas

To determine food abundance in upland, moderate-wet, and wet areas, ground surveys were conducted from late June –early July 2000 within the study area. Cluster sampling methods were used for data collections (Greenwood 1996). Three 100 m x 100-m areas were randomly selected on each upland, moderate-wet, and wet area. The same areas on each upland, moderate-wet, and wet area, which were used for microhabitat evaluations, were evaluated. Each side of a 100 m x 100-m area was divided into 10-m intervals, so that a total of 100 grid cells (10 m x 10 m) were established. Bank-side count methods (Perrow et al. 1996) were used to obtain small fish occurrences in individual cells (individual fish number was not counted.). The occurrence of potential food items (small fishes, and small ground nesting birds' eggs or chicks) was recorded for each cell by walking along the grid lines and visually assessing presence or absence of food items within each cell. The potential plant food items, such as berry fruits, were not detected in this study due to early fruit season. This method produced presence or absence data for 300 sample cells in each upland, moderate-wet, and wet area. Small mammals such as Siberian lemmings and collared lemmings could not be recorded in this study due to difficulties of detection.

For insects or spiders, because of their size and high abundance, two-stage sampling methods (Greenwood 1996) were used. Occurrences of insects or spiders were recorded within a small-scale cell (1 m x 1 m). A single 10 m x 10-m cell was randomly sampled within each 100 m x 100 m grid. Each side of the selected 10 m x 10-m cell was divided into 1-m intervals, providing a total of 100 small-scale cells from which to sample. This methodology produced presence or absence data for 300 small-scale sample cells for each landscape area type. Chi-square tests were used to evaluate differences in each food item occurrence among the three areas (upland, moderate-wet, and wet areas).

TIME ACTIVITY BUDGETS

Behavioral observations were attempted each day except during harsh weather conditions (snow storms, heavy rains and/or thick fog) from the beginning of June to the end of July 2000. Focal-animal sampling (Altmann 1974) was conducted during each crane behavioral observation. Behavior of single Lesser Sandhill Cranes and Siberian Cranes were observed from hills with the aid of 8 X binoculars or a 20 X –60 X spotting scope. Sampling methods of recording crane behaviors follow methods in Chavez-Ramirez (1996). During an observation session, one crane of a pair was followed visually for 30 consecutive min. During the 30 min, 120 instantaneous samples were collected by recording the behavior of the crane every 15 sec and classifying each behavior into one of the following categories; locomotion, foraging, rest, alert, and maintenance. A stopwatch timer was used to signal at 15-sec intervals. If the focal crane was lost from sight for longer than 5 consecutive min, the observation session was terminated for that individual. Only focal bird sessions, during which cranes were in sight for 30 min, were used in the analysis.

To standardize observation records and avoid observer bias, a single observer conducted all behavioral observations (Rosenthal 1976, Lehner 1996). Cranes were approached as slowly and quietly as possible to avoid detection. To reduce apprehending errors, behavioral activities of cranes were recorded from more than 1-km away from a hiding position, and the observation session was begun at least 30 min after the crane was located. Ethograms of cranes, followed Masatomi and Kitagawa (1975), Voss (1976), and Ellis et al. (1991, 1998), were used to identify the behavioral unit and record each category of crane behavior in the field.

Locomotion involved both ambulatory activities and flight. Ambulatory activities included walking, running, hopping, and leaping. Transitional action patterns to flight such as wing-spread-holding, preflight-posture, and run-flapping also were recorded as locomotion. Foraging were all those behaviors involving food capture attempts, food item handling, and consumption such as stabbing, pecking, nibbling, tugging, thrashing, bill-flicking, and bill-wiping. Drinking, noted infrequently, was included as foraging. Rest behaviors involved lying, sitting, standing (not in alert posture) or sleeping. Alert behavior involved bare-skin-expansion and tertial-elevation. During alert behavior, cranes stood with neck straight and head and beak parallel to the ground making a 90-degree angle (neck and beak). In contrast, during rest behavior, the neck showed a distinct curvature and the beak was pointed down with the beak and neck making an angle less than 90 degrees (Chavez-Ramirez 1996). Potential disturbances present in the study area included other cranes, arctic foxes, reindeer, wolves (*Canis lupus*) and brown bears (*Ursus arctos*). Maintenance activities involved plumage maintenance, such as preening, and comfort movements such as feather ruffling, rise-flapping, scratching, stretching, and shaking.

Results of behavioral activities were presented as the mean proportion of time for occurrences in different behavior activities of Lesser Sandhill and Siberian cranes. A Mann-Whitney *U* test was used to compare differences in the proportion of time occurrences on individual behaviors between Lesser Sandhill and Siberian cranes, and between the month (June and July) in different species. To establish time increments for analytical comparisons, behavioral observation data were pooled using 10-day intervals from 1 June–9 August 2000. A Kendall's tau test was used to evaluate the correlation between periods and occurrences of individual behaviors of both the Lesser Sandhill and Siberian cranes.

CHAPTER IV

CHARACTERIZATION OF NESTING SITE USING SPATIAL ANALYSIS

RESULTS

Characterization of study area

Composition and distribution of different landscape areas (ha) in the study area (30, 032 ha) were measured (Fig. 6). Following are the data from this analysis:

(1) Upland areas. Uplands comprised 2,400 ha representation 8% of the study area (Fig. 7). Forty-one high hills ranged from 20–60 m above sea level in the study area (Fig. 6) and covered 1,596 ha or 5.32% of the study area (Fig. 7). Twenty low hills (<20 m above sea level and above surrounding water level) covered 803 ha or 2.68% of the study area (Figs. 6 and 7). The low hill category was the smallest land cover in the study area.

(2) Moderate-wet areas. Moderate-wet (polygon) areas totaled 13,506 ha, that encompassed 44.97% of the study area (Fig. 7). The moderate-wet (polygon) area was the most abundant in the study area and constituted a major matrix feature for the GIS map (Fig. 6).

(3) Wet areas. Wet areas totaled 7,112 ha and were the second largest land cover area (23.68%) of the study site (Fig. 7). High basins were scattered throughout the study area with 291 locations totaling 9.66% of the study area (Figs. 6 and 7), and low basins covered wider areas than high basins. The average low basin area of 16 locations was 263 ha and 14.02% of the total study area (Figs. 6 and 7). These areas were flooded

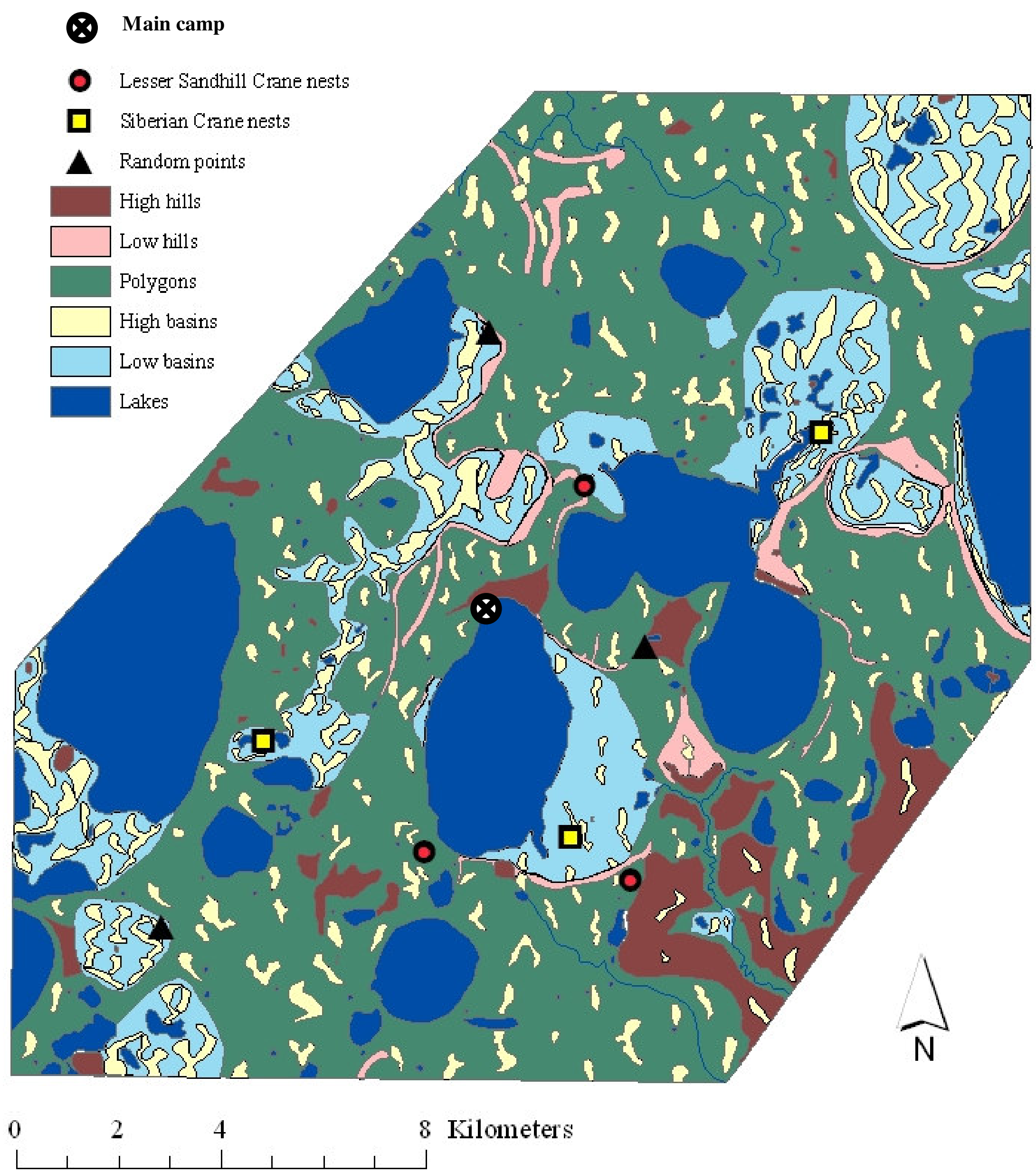


Fig. 6. The study area of Kytalyk Resource Reserve. Three Lesser Sandhill Crane nests, three Siberian Crane nests, and three random points were located within the study area in 2000. The location of the main camp was at 70° 50’ north latitude and 147° 30’ east longitude.

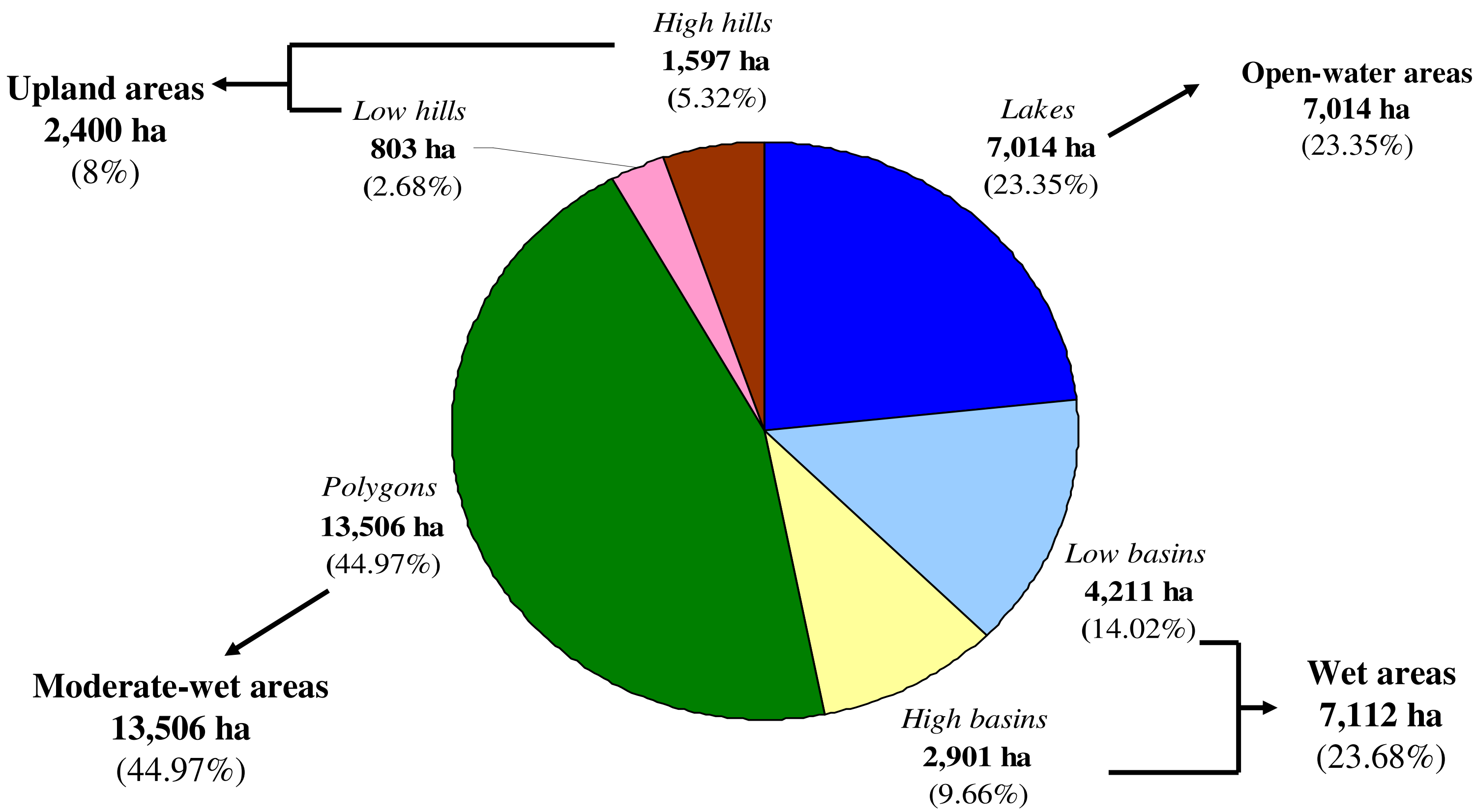


Fig. 7. Land cover (ha) and (%) of upland, moderate-wet, wet, and open-water areas, and six subdivided landscape types (high hills, low hills, polygons, high basins, low basins, and lakes) in the study area. Total area was 30,032 ha.

with 5 cm to 40 cm deep standing water and covered by low dense sedge glasses.

(4) Open-water areas. Open-water areas totaled 7,014 ha (23.35% of the study area) (Fig. 7). One hundred and fifty-seven lakes and ponds were recorded, and they had an average area of 45 ha (Fig. 6). Area cover sizes varied from the largest 17,756 ha lake to the smallest less than 1-ha pond (Fig. 6).

Nest searches

Three Lesser Sandhill Crane nests and three Siberian Crane nests were found within the nest search area, which was approximately a 7 km radius area from the main campsite. Their locations are shown in Figure 6.

Mean distances and mean areas of crane nests

Distances between three nests of Lesser Sandhill Crane were 4,046 m, 7,749 m, and 7,830 m with a mean distance of 6,542 m. The mean of the shortest distances from each Lesser Sandhill Crane nest to a conspecific nest was 5,280 m. The minimum mean area per Lesser Sandhill Crane nest was 2,188 ha (21.88 km^2).

Distances between three nests of Siberian Cranes were 6,281 m, 9,331 m, and 12,451 m with a mean distance of 9,354 m. The mean of the shortest distances from each Siberian Crane nest to conspecific nest was 7,297 m. The minimum mean area per Siberian Crane nest was 4,191 ha (41.91 km^2).

There were no significant ($P = 0.261$) differences in mean variations of shortest conspecific distances between nests of Lesser Sandhill and Siberian cranes (Fig. 8). A

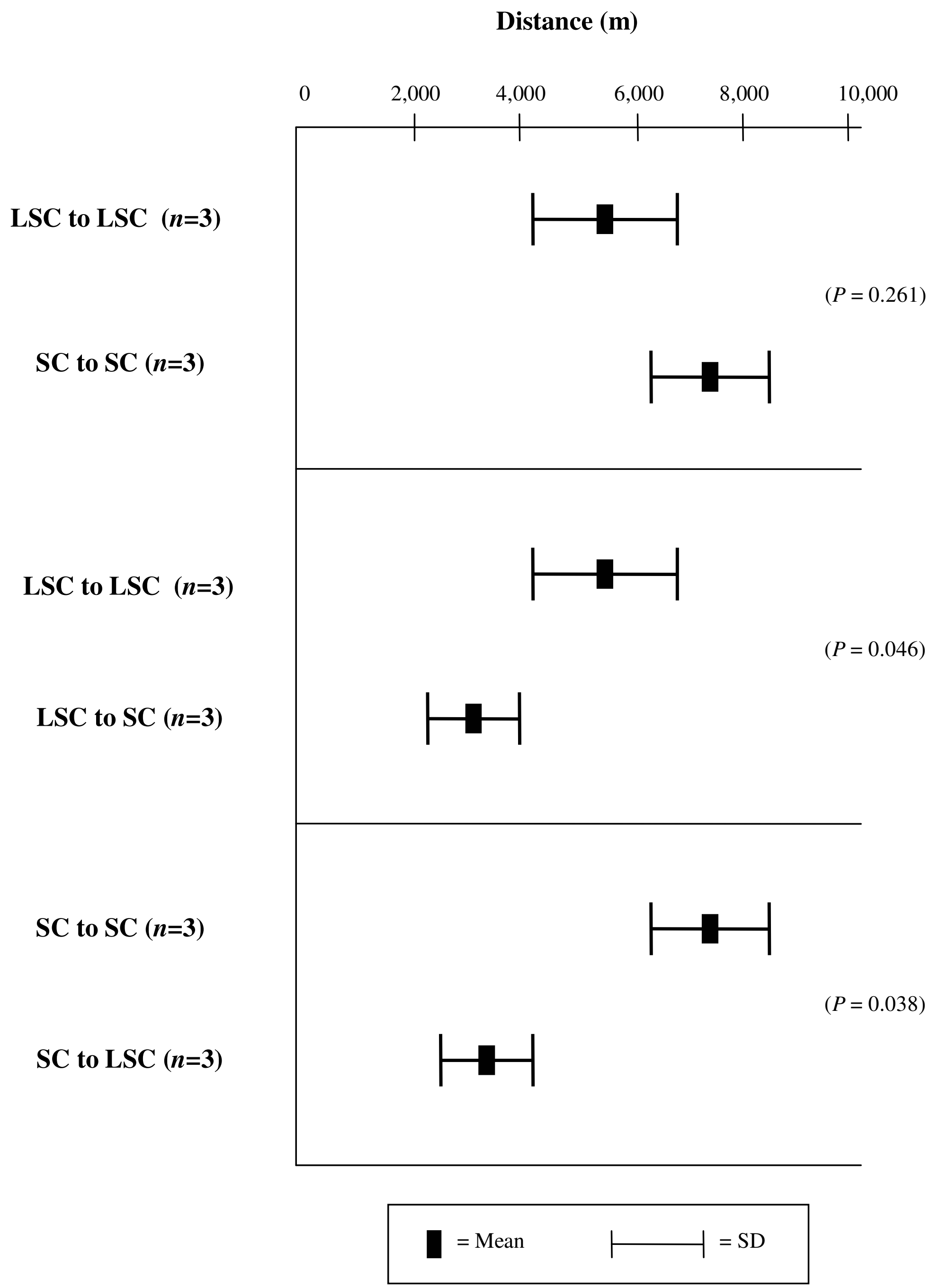


Fig. 8. Mean of the shortest distance between conspecific and heterospecific nests of Lesser Sandhill Crane (LSC) and Siberian Crane (SC) within the nest search area in 2000. (*n*) is a number of distances between nests. *P*-values were based on results of a Mann-Whitney *U* test.

shortest distance comparison between Lesser Sandhill Crane nests to conspecific nests: a mean 5,280 m (SD = 1,234), and heterospecific nests: a mean 3,032 m (SD = 913), showed significant ($P = 0.046$) differences (Fig. 8). A shortest distance comparison between Siberian Crane nests to conspecific nests: a mean 7,297 m (SD = 1,016), and heterospecific nests: a mean 3,337 m (SD = 944), also showed ($P = 0.038$) significant differences (Fig. 8). Nests of Lesser Sandhill Cranes and Siberian Cranes were further apart to conspecific nests than to nests of heterospecific.

Landscape components at various distances around crane nests

Three points were randomly selected for comparison as control points. These random points are shown in Figure 6.

Landscape types surrounding nests of Lesser Sandhill and Siberian cranes gradually changed from area surrounding nest sites to areas at the 2,000-m buffer ranges (Fig. 9). Polygons were the major surrounding landscape type of Lesser Sandhill Crane nests and random points. Low basins were the primary surrounding landscape type of Siberian Crane nests.

Distribution of mean area (ha) of each landscape type within each radius buffer area were different for Lesser Sandhill Crane nests, Siberian Crane nests, and random points (Fig. 9). Distributions of surrounding landscape types for Lesser Sandhill Crane nests and Siberian Crane nests were not significantly ($F = 2.364$, df = 5, $P = 0.071$) different after the 1,200-m radius buffer. The comparisons between Lesser Sandhill Crane nests and random points were not significant ($F = 0.872$, df = 5, $P = 0.514$) after

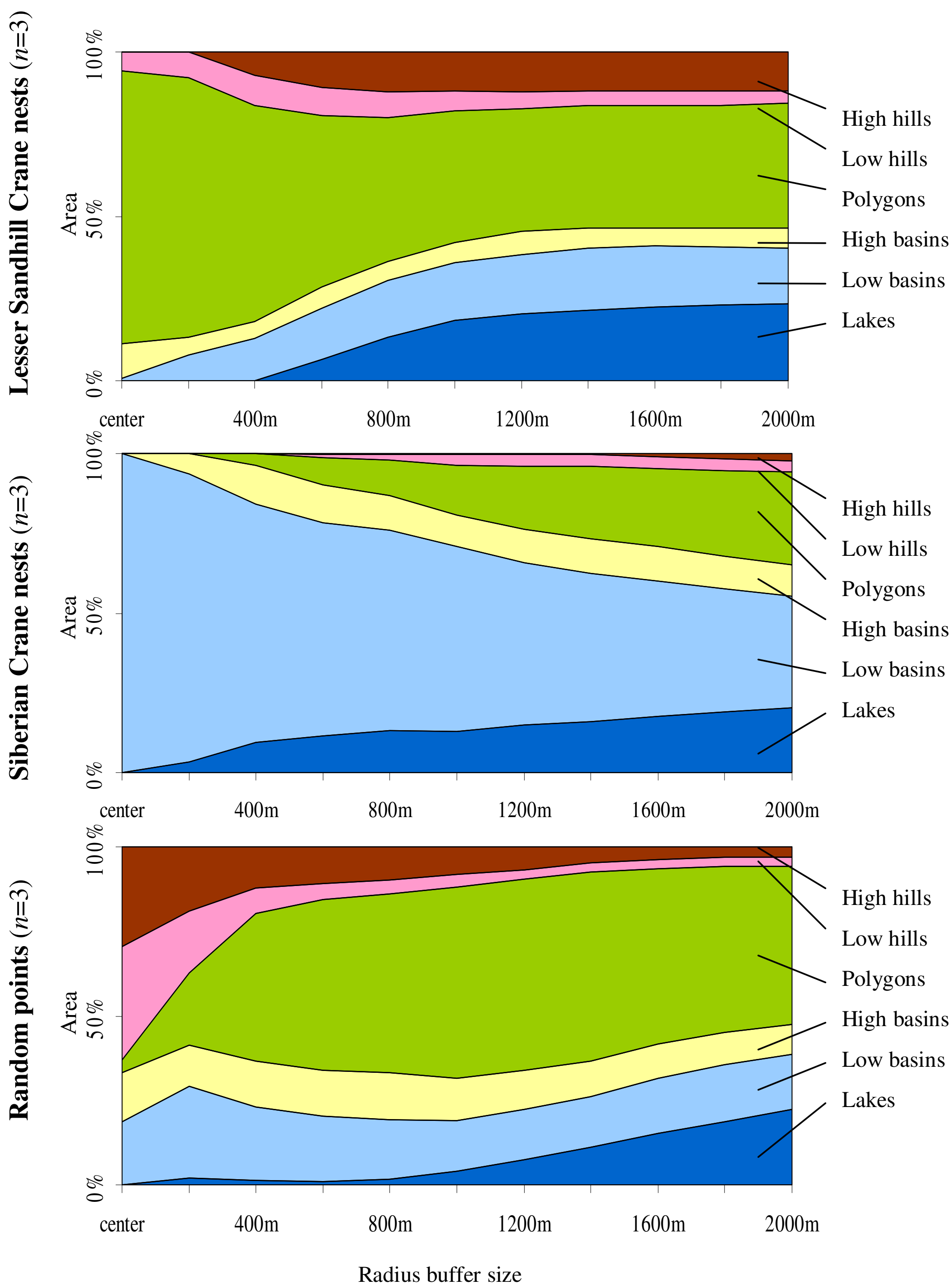


Fig. 9. Landscape types of buffer areas surrounding nests and random points within the study area in 2000.

the 400-m radius buffer. The comparison between Siberian Crane nests and random points was not significantly ($F = 2.172$, df = 5, $P = 0.091$) different after the 2,000-m radius buffer.

Microhabitat evaluations of crane nest sites

Three Lesser Sandhill Crane nest areas (total 90 quadrat plots) and three Siberian Crane nest areas (total 90 quadrat plots) were sampled. To compare nest site habitat characteristics, a total of 355 random quadrat plots was sampled as control sites.

Means of water depth (cm), vegetation height (cm), and vegetation cover (%) of Lesser Sandhill Crane nest areas were 5.54 cm (SD = 0.68), 20.12 cm (SD = 1.08), and 76.28% (SD = 3.08), respectively. Means of water depth (cm), vegetation height (cm), and vegetation cover (%) of Siberian Crane nest areas were 10.5 cm (SD = 0.56), 26.51 cm (SD = 0.86), 42.39% (SD = 2.77), respectively. Means of water depth (cm), vegetation height (cm), and vegetation cover (%) of random sites were 3.96 cm (SD = 0.33), 15.93 cm (SD = 0.51), and 81.81% (SD = 1.59), respectively.

Siberian Crane nest areas were at significantly higher water levels, taller vegetation, and lower vegetation cover than Lesser Sandhill Crane nest areas or random sites (Table 1 and Fig. 10). Nests of Lesser Sandhill Cranes were located in sites with lower water levels than Siberian Crane nests, but still significantly higher water levels than random sites (Table 1 and Fig. 10). Vegetation height of Lesser Sandhill Crane nest areas was shorter than Siberian Crane nest areas, but taller than random sites (Table 1 and Fig. 10). Vegetation cover of Lesser Sandhill Crane nests was much higher than

Table 1. Comparison of water depth (WA), vegetation height (VH), and vegetation cover (VC) in Lesser Sandhill Crane nest areas (LSC), Siberian Crane nest areas (SC), and random sites (RA) within the study area in 2000. *P*-values were based on results of Kruskal-Wallis tests and Mann-Whitney *U* tests. (*n*) indicates number of quadrat samples.

Category	Comparison (*n*)	X^2	df	*P*
Water depth (cm)	LSC (90) vs. SC (90) vs. RA (355)	94.09	2	<0.001[a]
	LSC (90) vs. SC (90)			<0.001[b]
	LSC (90) vs. RA (355)			0.018[b]
	SC (90) vs. RA (355)			<0.001[b]
Vegetation height (cm)	LSC (90) vs. SC (90) vs. RA (355)	82.14	2	<0.001[a]
	LSC (90) vs. SC (90)			<0.001[b]
	LSC (90) vs. RA (355)			<0.001[b]
	SC (90) vs. RA (355)			<0.001[b]
Vegetation cover (%)	LSC (90) vs. SC (90) vs. RA (355)	113.94	2	<0.001[a]
	LSC (90) vs. SC (90)			<0.001[b]
	LSC (90) vs. RA (355)			0.054[b]
	SC (90) vs. RA (355)			<0.001[b]

[a] Kruskal-Wallis

[b] Mann-Whitney *U*

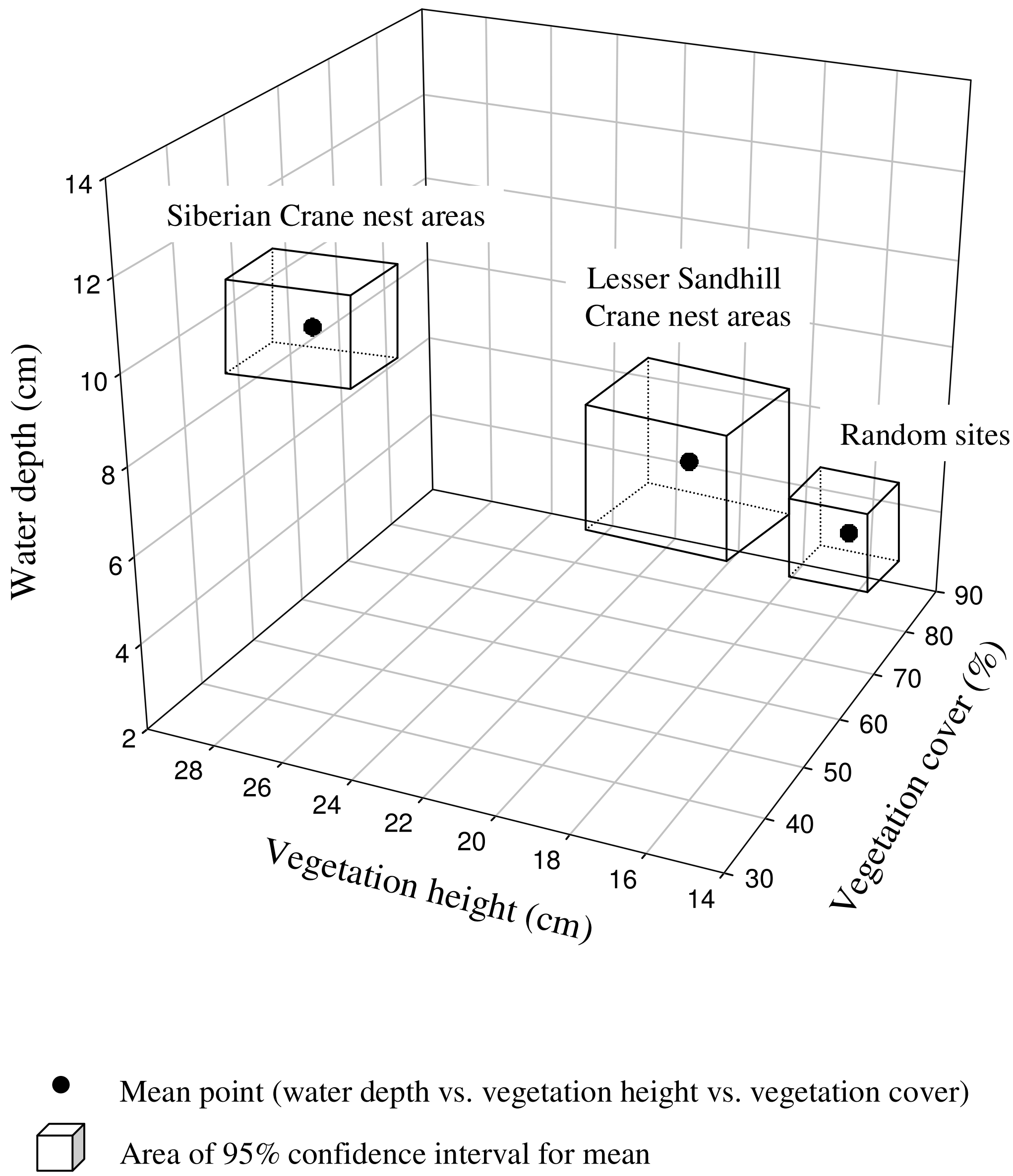


Fig. 10. Mean and 95% confidence interval for water depth, vegetation height and vegetation cover in three different sample locations within the study area in 2000: Lesser Sandhill Crane nest areas, Siberian Crane nest areas, and random sites.

Siberian Crane nest areas, but there was no significant differences with random sites (Table 1 and Fig. 10).

Thirty-six major plant species in the study area were found and categorized to 5 different physiognomic (appearance and growth form) groups; *Carex* spp, Moss, Tussocks, Forbs, and Shrubs (Table 2). Four species of *Carex* spp. (*Carex chordorrhiza*, *C. rariflora*, *C. rotundata*, and *C. stans*.) were identified. In the Moss group, I identified six species; *Aulacomnium* spp., *Cladonia* spp., *Hylocomium* spp., *Orthothecium* spp., *Pleurosium* spp., and *Thmenthypnum* spp. I recorded 10 general species as the Tussock group; *Alopecurus* spp., *Equisetum* spp., *Eriophorum angustifolium*, *E. callitrix*, *E. vaginatum*, *Fesuca* spp., *Kobresia sibirica*, *Luzula* spp., *Poe* spp., and *Trichophorum* spp. In addition, I identified 12 general species as a forb group; *Anemone* spp., *Cassiope* spp., *Chrysosplenium* spp., *Diapensia* spp., *Dryas* spp., *Loiseleuria* spp., *Oxytropis* spp., *Potentilla* spp., *Ranunculus* spp., *Rubus chamaemorus*., *Saxifraga* spp., *Vaccinium* spp. And lastly, I recorded four species for the Shrub group; *Betula* spp., *Ledum* spp., *Salix pulchra*, and *S. polaris*.

Table 3 shows the mean of vegetation cover (%) for each vegetation group within quadrat plot around each nest area and random sites. In three different locations (the Lesser Sandhill Crane nest areas, the Siberian Crane nest areas, and the random sites), distributions of each vegetation group cover were significantly different (Table 4 and Fig. 11). Each vegetation cover of *Carex* spp. and shrubs around Lesser Sandhill Crane nests was significantly higher than at random sites (Table 4 and Fig. 11). Siberian Crane nest areas had low vegetation cover with the majority of vegetation of the *Carex* spp. group

Table 2. List of vegetation groups and species, which were found and identified within 0.25 m x 0.25 m quadrat sample plots in the study area in July 2000.

Vegetation group	Species
Carex spp.	*Carex chordorrhiza*
	C. rariflora
	C. rotundata
	C. stans
Moss	*Aulacomnium* spp.
	Cladonia spp.
	Hylocomium spp.
	Orthothecium spp.
	Pleurosium spp.
	Thmenthypnum spp.
Tussocks (Exclude *Carex* spp.)	*Alopecurus* spp.
	Equisetum spp.
	Eriophorum angustifolium
	E. callitrix
	E. vaginatum
	Fesuca spp.
	Kobresia sibirica
	Luzula spp.
	Poe spp.
	Trichophorum spp.
Forbs	*Anemone* spp.
	Cassiope spp.
	Chrysosplenium spp.
	Diapensia spp.
	Dryas spp.
	Loiseleuria spp.
	Oxytropis spp.
	Potentilla spp.
	Ranunculus spp.
	Rubus chamaemorus
	Saxifraga spp.
	Vaccinium spp.
Shrubs	*Betula* spp.
	Ledum spp.
	Salix pulchra
	S. polaris

Table 3. Mean ± SD of vegetation cover (%) for each vegetation group within a 0.25m x 0.25m quadrat plot around Lesser Sandhill Crane nest areas, Siberian Crane nest areas, and random sites in the study area in 2000.

	Mean ± SD (%)					Total vegetation
Location	*Carex* spp.	Moss	Tussocks	Forbs	Shrubs	cover mean±SD
Lesser Sandhill Crane nest areas (*n*=90)	27.47±3.05	14.3±1.82	7.99±1.66	7.16±1.49	19.21±2.52	76.28±3.08 (%)
Siberian Crane nest areas (*n*=90)	36.23±2.29	4.81±1.4	0.39±0.39	0	0.63±0.32	42.39±2.77 (%)
Random sites (*n*=356)	17.75±1.42	18.96±1.12	18.38±1.31	13.21±1.07	13.18±0.92	81.16±1.59 (%)

Table 4. Comparisons of vegetation cover (%) around Lesser Sandhill Crane nest areas (LSC), Siberian Crane nest areas (SC), and random sites (RA) in the study area in 2000. *P*-values were based on results of Kruskal-Wallis tests and Mann-Whitney *U* tests. (*n*) indicates number of quadrat samples.

Category	Comparison (*n*)	x^2	df	*P*
Carex spp. (%)	LSC (90) vs. SC (90) vs. RA (355)	65.73	2	<0.001[a]
	LSC (90) vs. SC (90)			0.009[b]
	LSC (90) vs. RA (355)			0.003[b]
	SC (90) vs. RA (355)			<0.001[b]
Moss (%)	LSC (90) vs. SC (90) vs. RA (355)	45.31	2	<0.001[a]
	LSC (90) vs. SC (90)			<0.001[b]
	LSC (90) vs. RA (355)			<0.001[b]
	SC (90) vs. RA (355)			0.048[b]
Tussocks (%)	LSC (90) vs. SC (90) vs. RA (355)	82.14	2	<0.001[a]
	LSC (90) vs. SC (90)			<0.001[b]
	LSC (90) vs. RA (355)			<0.001[b]
	SC (90) vs. RA (355)			<0.001[b]
Forbs (%)	LSC (90) vs. SC (90) vs. RA (355)	56.84	2	<0.001[a]
	LSC (90) vs. SC (90)			<0.001[b]
	LSC (90) vs. RA (355)			<0.001[b]
	SC (90) vs. RA (355)			0.028[b]
Shrubs (%)	LSC (90) vs. SC (90) vs. RA (355)	62.19	2	<0.001[a]
	LSC (90) vs. SC (90)			<0.001[b]
	LSC (90) vs. RA (355)			<0.001[b]
	SC (90) vs. RA (355)			0.039[b]

[a] Kruskal-Wallis
[b] Mann-Whitney *U*

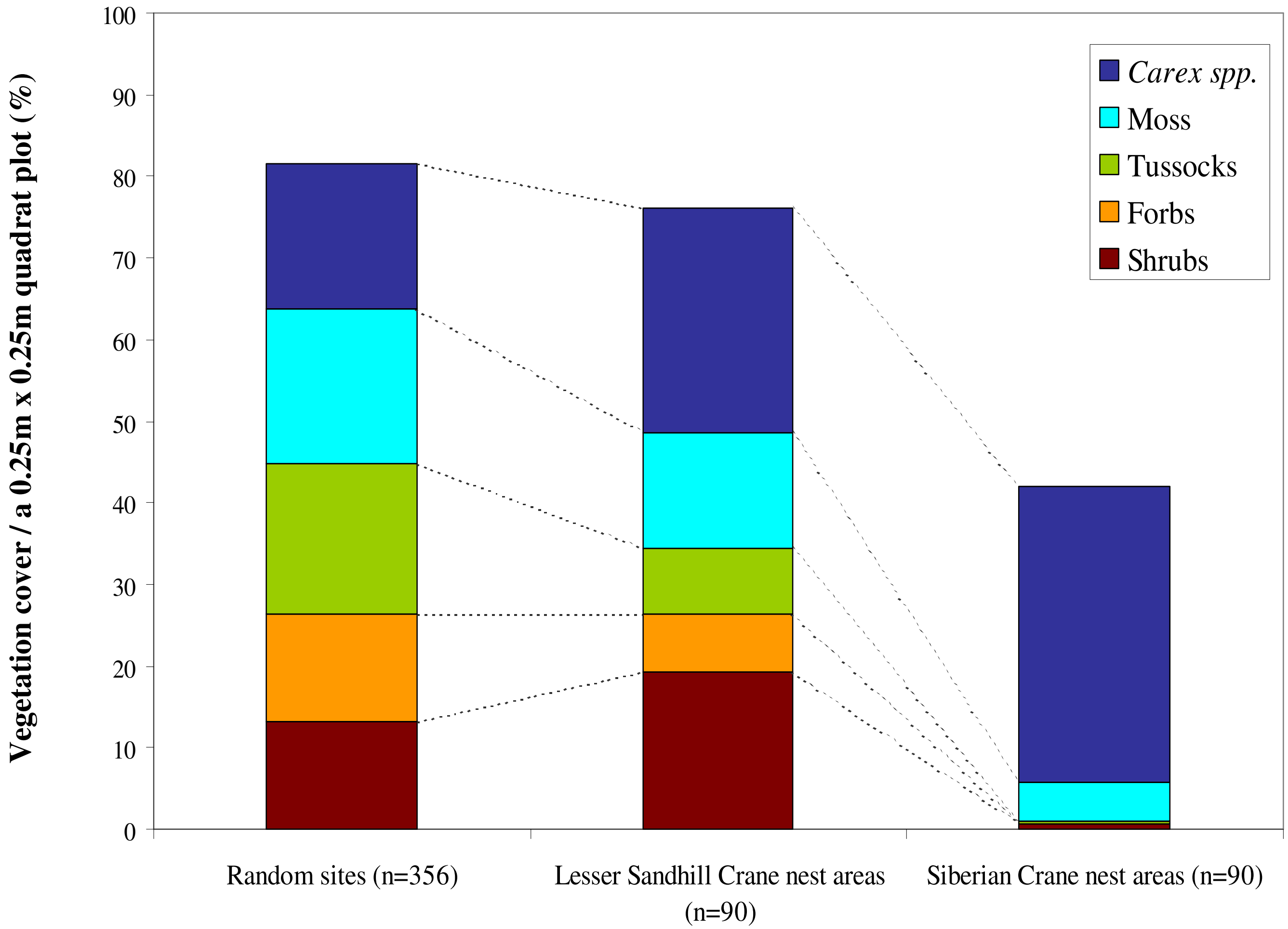


Fig. 11. Relative dominance (%) of vegetation cover for each vegetation type around random sites, Lesser Sandhill Crane nest areas, and Siberian Crane nest areas within the study area in 2000.

(Fig. 11). The 36.23% of *Carex* spp. cover at Siberian Crane nests was significantly higher than other locations (Tables 4 and Fig. 11).

DISCUSSION

Nest searches

Because of the location of the nest search area and characteristics of cranes, only three nests of each species were found during this investigation. Lesser Sandhill Cranes were well camouflaged by their plumage, especially in moderate-wet (polygon) areas. In one case, a Lesser Sandhill Crane that was incubating on its nest remained unseen less than 10-m away. Walkinshaw (1973) described a similar experience in which a crouched Lesser Sandhill Crane suddenly appeared about 12 m from him while he was walking across the tundra on Banks Island. It is possible that there were more nests of Lesser Sandhill Cranes than could be found in the nest search area. I observed 2 or 3 other unidentified pairs infrequently which was chased by other cranes around the nest search areas. I assumed they were not nesting pairs because 2 cranes of these pairs were walking around closely together during incubation period in June. These unidentified pairs could be early nest failures or new pairs that were establishing their potential nesting territories for future breeding.

Siberian Cranes were considerably easier to find because of their mostly white plumage. For example, one incubating Siberian Crane was spotted more than 5 km away from the observation site. Despite the ease of observation, only three pairs' nests of the endangered Siberian Cranes were found.

In order to increase sample sizes of Siberian Cranes in future research efforts, the nest search area should be expanded because of the species' low population sizes. For future Lesser Sandhill Crane investigations, moderate-wet (polygon) areas should be targeted to find more nests since these areas had been used as their nest sites (Fig. 9).

Mean distances and mean areas of crane nests

Results show that Lesser Sandhill Crane exhibited differences in nest placement from that of Lesser Sandhill Crane nesting in Alaska or Banks Island (e.g., Boise 1977, Walkinshaw 1965*a*, 1981; Reed 1988). Boise (1977) found the shortest distance between Lesser Sandhill Crane nests was 277 m with nesting densities of Lesser Sandhill Cranes on the Yukon – Kuskokwim Delta, Alaska of 0.54 / km^2 in 1975 and 0.78 / km^2 in 1976. Walkinshaw (1965*a*, 1981) observed that the two closest nests were slightly over 1,000 m apart and one pair every 16.5 km^2 on Banks Island in 1964. In a Lesser Sandhill Crane study by Reed (1988), the mean of the closest nests was 2,230 m, and the mean area of nests was estimated at 11.4 km^2 on Banks Island in 1976. The mean distance of the closest nests of Lesser Sandhill Cranes in this study was 5,280 m (SD = 1,234) with the shortest distance of 4,046 m. Even though the minimum mean area per Lesser Sandhill Cranes nest was estimated in this study, the area of 21.88 km^2 was much larger than nesting Lesser Sandhill Cranes in Alaska and Banks Island. Therefore, Lesser Sandhill Cranes in this study exhibited lower nest densities than nesting Lesser Sandhill Cranes in Alaska and Banks Island. Alaska coastal tundra and Banks Island have been historically known as the Lesser Sandhill Crane breeding areas. In fact, nesting records of Lesser Sandhill Cranes have been increasing during the last few decades in this study area (N. I. Germagenov per. comm. Yakutsk Institute of Biology). There is a high likelihood that populations of Lesser Sandhill Cranes will expand more into the study area in the future and may lead to smaller nesting area.

Actual territory sizes of Siberian Cranes were unknown. Degtyaryov and Lubutin (1991) reported that density of Siberian Cranes (2.5 cranes per 100 km^2 in 1985; 1.7/100 km^2 in 1987; and 2.63/100 km^2 in 1989) in and around the Kytalyk Resource Reserve. A more recent study (Germogenov 1998) suggested that there were 5.4 cranes/100 km^2 within 1,314 km^2 based on his aerial and ground surveys in the Kytalyk Resource Reserve during 1993 – 1997. My result showed a minimum mean area of 41.91 km^2 for Siberian Crane nest. From the mean area, an estimated density of Siberian Crane nests in the nest search area was 2.4 nests (pairs)/100 km^2, which suggests approximately 5 cranes/100 km^2. This density estimation was similar to the results of Germogenov (1998). The three nests would be near the limit for Siberian Cranes in this nest search area.

The study results indicated that the shortest distances from each species to conspecific nests were not significantly different. Both the Lesser Sandhill Cranes and the Siberian Cranes maintained long distances between conspecific nests. However, it is possible that if the number of Lesser Sandhill Crane pairs increased in this area, the average distances of Lesser Sandhill Crane nests to conspecific nests would likely become closer, which is similar to the historically known Alaskan and Banks Island cranes.

Distances between nests of heterospecific were much closer than conspecific nests. I observed Lesser Sandhill Cranes feeding approximately 1 km away from a Siberian Crane nest. Lesser Sandhill Cranes were chased by Siberian Cranes when Lesser Sandhill Cranes approached less than 1 km from Siberian Crane nests. A pair of Siberian Cranes chased another Siberian Crane, when the intruder came within at least 2 km of the pair's nest. I also observed a pair of Lesser Sandhill Cranes chase another Lesser Sandhill Crane often, but I did not observe agonistic interactions in which Lesser Sandhill Cranes chased Siberian Cranes on the study area. The study result suggested that both species were more territorial toward conspecific species than toward heterospecific species.

Landscape components at various distances around crane nests

This study suggested that Lesser Sandhill and Siberian cranes selected different components of the landscape for nest sites. Differences of components of landscape types occurred within a 1,200-m radius buffer area from their nests (Fig. 9). Lesser Sandhill Cranes primary used moderate-wet (polygon) areas that consisted of hummock mounds surrounded by scattered water, and Siberian Cranes primarily used flat, open-wide low basin with flooded water within the 1,200-m radius-buffer areas.

Within the 400-m radius-buffer area (about 50 ha) around Lesser Sandhill Crane nests, a significantly different distribution of landscape types was observed compared to random points (Fig. 9). These differences indicated Lesser Sandhill Cranes have smaller scale habitat component requirements than Siberian Cranes. Particularly, all Lesser

Sandhill Cranes nested in moderate-wet (polygon) areas, which occupied more than 66% (about 33 ha) of the total ground cover within a 400-m radius-buffer area of Lesser Sandhill Crane nests (Fig. 9). Sandhill Cranes in this study apparently select moderate-wet (polygon) habitats for nesting. Moderate-wet (polygon) areas also were the primary land cover with 44.97% (13,506 ha) of the total study area (Fig. 7). Therefore, there were more potential nest sites available for Lesser Sandhill Cranes within this study area.

Components of landscape types within a 2,000-m (about 1,257 ha) radius from Siberian Crane nests were significantly different than random points (Fig. 9). Indeed, all Siberian Crane nests were found in low basin, which covered a greater amount (435 ha) of total ground cover within a 2,000-m radius-buffer area from Siberian Crane nests (Fig. 9). A large amount of low basin may be necessary for Siberian Cranes to nest; however, only 14% (4,211 ha) of the total study area was covered by low basin in this study area (Fig. 7). Therefore, Siberian Cranes had more specific requirements for their nesting habitat, and Siberian Crane nest sites were more limited than the potential nest sites of Lesser Sandhill Cranes in this study area.

Microhabitat evaluations of crane nest sites

All Lesser Sandhill Crane nests were found on raised mounds (about 3 m across) surrounded by small pools (<10 m wide) and water channels (about 1-m wide) created by polygonal formations. Walkinshaw and Stophlet (1949) found two Lesser Sandhill Crane nests on similar landscape types along the Johnson River, about 50 km west of Bethel, Alaska in 1946. When Lesser Sandhill Cranes initiated nesting in early June, considerable snow still covered open-flat ground except surfaces of the hummock mounds in moderate-wet (polygon) areas (T. Watanabe pers. observ.). The predominant plumage of colors was similar to the bird's usual environment (Gill 1989). Lesser Sandhill Cranes were well camouflaged by their brown feathers in the moderate-wet (polygon) environment. Mixtures of brown patches of hummocks and white snow mosaic appearances provide perfect hiding places from potential predators, such as arctic foxes (Reed 1988), wolves (Tacha et al. 1992), and possibly brown bears, for incubating Lesser Sandhill Cranes. Characteristics of polygon formation (mixtures of brown patches of hummocks surrounded by water and white snow mosaic appearances) might be the main factor in determining nest sites of Lesser Sandhill Cranes rather than vegetation covers, which was still under snow at beginning of nesting time. Boise (1977) also noted that nest site selections of Lesser Sandhill Cranes in Alaska might be due to snow cover. Total vegetation cover around Lesser Sandhill Crane nests was not significantly different than random sites. This also may indicate that vegetation cover may not be the primary factor in nest site selection; however, moderate-wet (polygon) areas exhibited different types of vegetation groups than random sites.

The existence of polygon wedge-crack pools or channels around Lesser Sandhill Crane nest sites had a mean water depth of 5.5 cm and a mean vegetation height of 20 cm, with water depth and vegetation height significantly higher than for random sites. These mixtures of dry and wet grounds formation made combinations of more shrubs and taller *Carex* spp. vegetations than random sites. Short weedy shrub twigs and old *Carex* spp. were used for nest construction as described by Walkinshaw (1965*a*, 1973).

During the incubation period in mid- June, snow melted around Lesser Sandhill Crane nests and the ground vegetation was exposed. Taller *Carex* spp. partially hid incubating Lesser Sandhill Cranes from predators approaching by ground, and higher water level in polygon wedge-crack pools or channels makes a predator's approach to the nest difficult.

The three Siberian Crane nests were found on low basins, and nests were located closer to open-water (T. Watanabe pers. observ.). Low basin habitats ensured high visibility, which enabled Siberian Cranes to detect ground-approaching predators from a great extent.

Siberian Cranes initiated incubation in early June while low basins were still covered by snow with little vegetation exposed. Water was still frozen and ground predators such as arctic foxes (Perfilyev 1965) could easily approach nests in low basins. As Snowy Owls (*Nyctea scandiaca*) wore white plumages that resembled their arctic surroundings (Welty and Baptista 1988), white plumage of Siberian Cranes provided cryptic coloration for incubating Siberian Cranes on the wide open low basin environment.

Once snow melted, Siberian Cranes were visible from high hills more than 5 km away (T. Watanabe per. observ.). This white coloration makes Siberian Cranes conspicuous to conspecifics, and presumably facilitates defense of the breeding territory in open wet area (Meine and Archibald 1996). At the same time, Siberian Cranes may become conspicuous to predators; however, high water levels in vast wide-open low basin areas sheltered them from many ground-approaching predators. The study results indicated that nest sites of Siberian Cranes were surrounded by water more than 10-cm deep and vegetation more than 27-cm tall, which were significantly higher than for random sites. The high vegetation cover of *Carex* spp. was one of the nest site characteristics of Siberian Cranes. The taller *Carex* spp. might hide incubating white Siberian Cranes from ground predators as well.

CHAPTER V

HABITAT USE PATTERNS IN RELATION TO FOOD ABUNDANCE AND MICROHABITAT EVALUATION

RESULTS

Habitat use patterns of Lesser Sandhill Cranes and Siberian Cranes

A total of 45 observation days was made at sites used by Lesser Sandhill Cranes and 43 observation days of sites used by Siberian Cranes (Table 5). There were differences between habitat-use patterns of Lesser Sandhill and Siberian cranes among upland, moderate-wet, and wet areas. Lesser Sandhill Cranes were observed primarily in moderate-wet areas, while Siberian Cranes were observed primarily in the wet areas (Fig. 12).

Lesser Sandhill Cranes were observed 6 days, and Siberian Cranes were observed 3 days in upland areas (Table 5). In moderate-wet areas, Lesser Sandhill Cranes were located 41 days, and Siberian Cranes were observed 5 days. In wet areas, Lesser Sandhill Cranes were located 9 days, and Siberian Cranes were observed 40 days.

Survey data were pooled monthly to evaluate habitat-use pattern changes of Lesser Sandhill and Siberian cranes in June 2000 and July 2000 (Fig. 13). Lesser Sandhill and Siberian cranes were observed in upland areas 6 and 3 times respectively in June; however, they were not observed in upland areas in July. Lesser Sandhill Cranes were regularly observed in moderate-wet areas throughout both months. Siberian Cranes

Table 5. Number (*n*) of days of Lesser Sandhill Cranes and Siberian Cranes observed in each upland, moderate-wet, and wet area from beginning of June to end of July 2000.

Species	Month	Area						
		Upland		Moderate-wet		Wet		Total days
		n	%	*n*	%	*n*	%	
Lesser Sandhill Crane	June	6	24	21	84	6	24	25
	July	0	0	20	100	3	15	20
	Total	6	13.3	41	91.1	9	20	45
Siberian Crane	June	3	12.5	4	16.7	22	91.7	24
	July	0	0	1	5.3	18	94.7	19
	Total	3	7	5	11.6	40	93	43

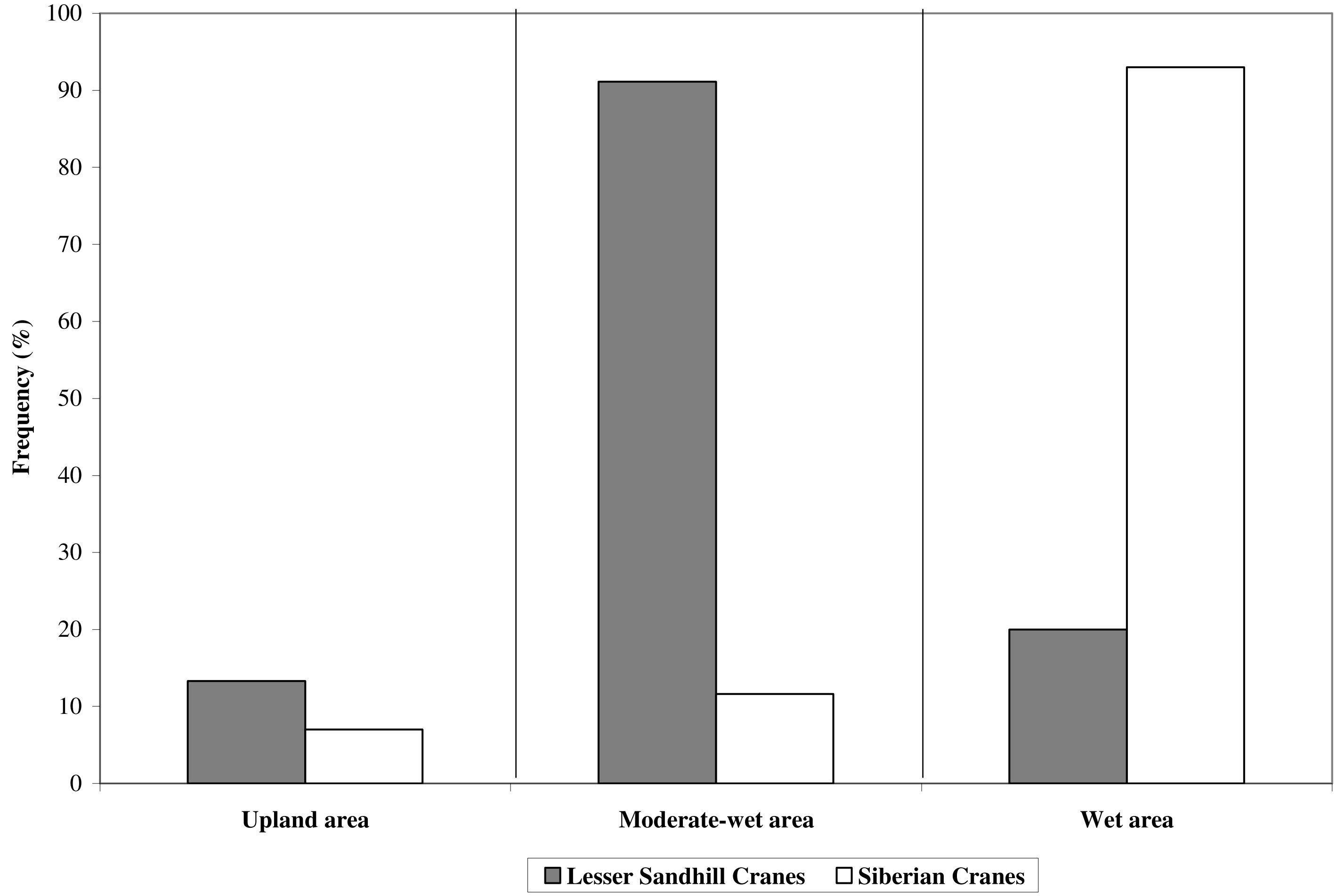


Fig. 12. Frequency of days of Lesser Sandhill Cranes and Siberian Cranes observed in upland, moderate-wet, and wet areas within the study area in 2000.

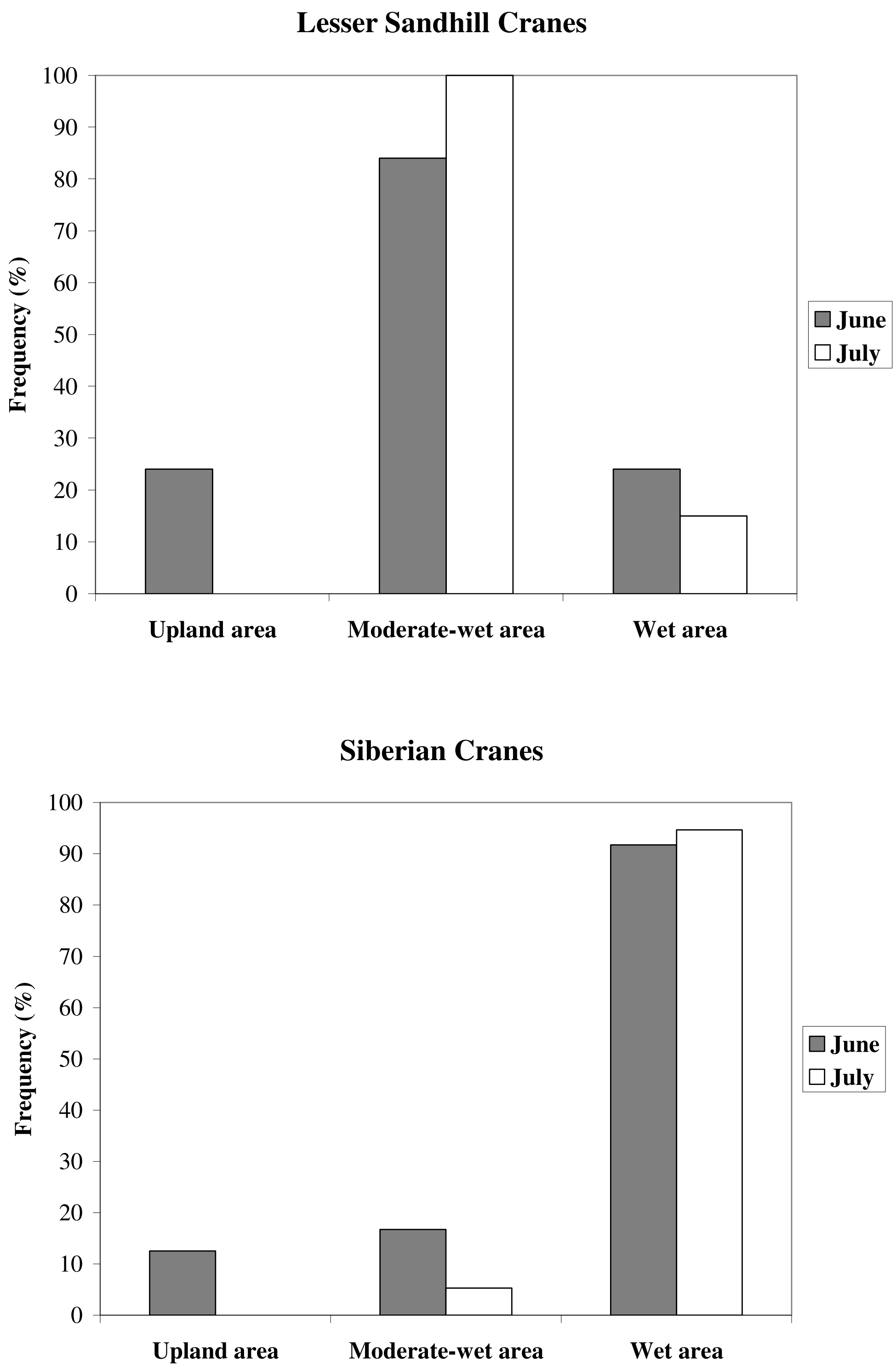


Fig. 13. Frequency of observation changes of Lesser Sandhill Cranes and Siberian Cranes in upland, moderate-wet, and wet areas within the study area in June 2000 and July 2000.

were observed in moderate-wet areas only 4 days in June, and a single time in July. Lesser Sandhill Cranes were located in wet area 6 days in June and 3 days in July, and they more frequently used wet areas in June. Siberian Cranes were regularly observed in wet areas throughout both months.

Microhabitat evaluations of upland, moderate-wet, and wet areas

Means of water depth (cm), vegetation height (cm), and vegetation cover (%) of upland areas were 0.04 cm (SD = 0.02), 8.13 cm (SD = 0.38), and 99.83% (SD = 0.12), respectively. Means of water depth (cm), vegetation height (cm), and vegetation cover (%) of moderate-wet areas were 2.7 cm (SD = 0.44), 14.07 cm (SD = 0.62), 83.22% (SD = 2.95), respectively. Means of water depth (cm), vegetation height (cm), and vegetation cover (%) of wet areas were 10.58 cm (SD = 0.57), 20.39 cm (SD = 0.69), and 36.61% (SD = 3.06), respectively.

Wet areas had significantly higher water levels, taller vegetation, and lower vegetation cover than other areas (Table 6, and Fig. 14). Moderate-wet areas had lower water depths, shorter vegetation heights, and greater vegetation cover than wet areas, but taller vegetation height, greater water depths, and lower vegetation covers than upland areas (Table 6, and Fig. 14). Upland areas had lower water depths, lower vegetation height, and greater vegetation cover than other areas (Table 6, and Fig. 14).

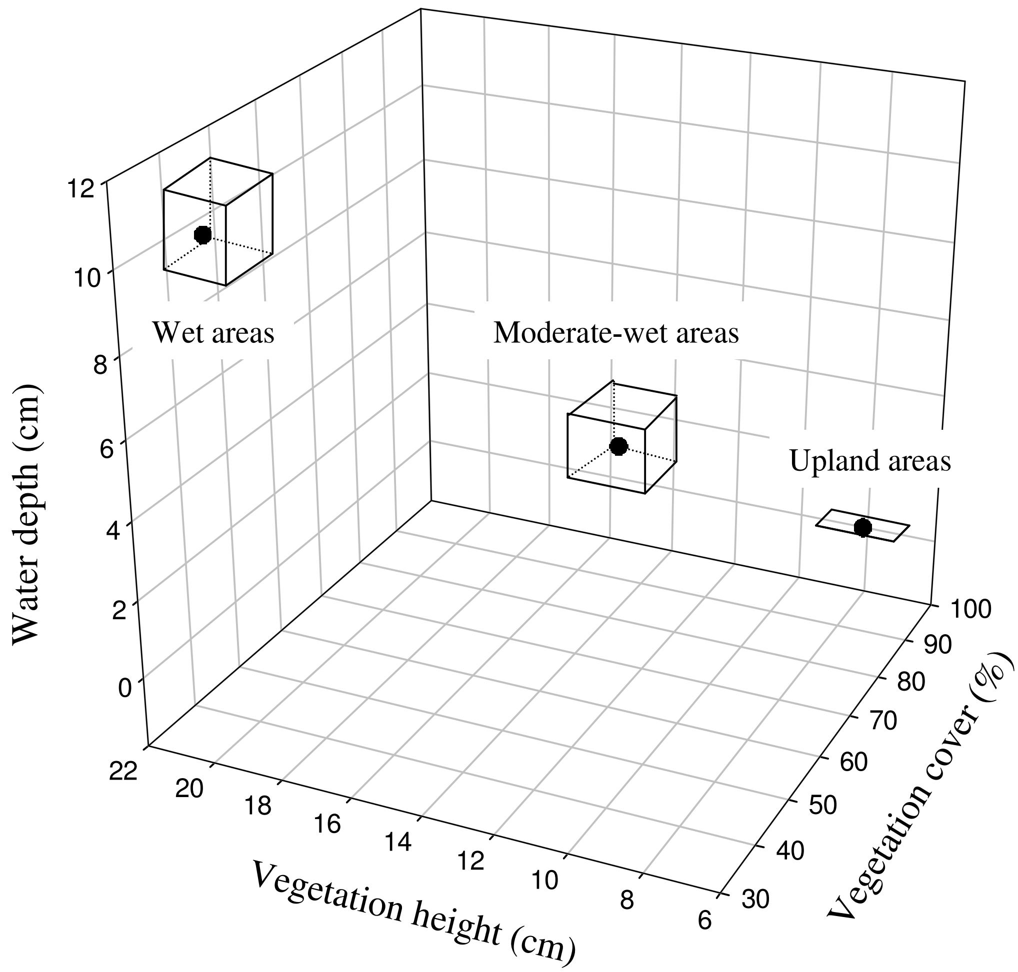
Total vegetation cover of upland areas was more than 99% (Table 7). Upland areas were covered with all vegetation groups except *Carex* spp. (Table 7). Tussock was the largest cover vegetation group (38%) in the upland area (Table 7, and Fig. 15), and

Table 6. Comparison of water depth (WA), vegetation height (VH), and vegetation cover (VC) in upland areas (UP), moderate-wet areas (MW), and wet areas (WE) in the study area in 2000. *P*-values were based on results of Kruskal-Wallis tests and Mann-Whitney *U* tests. (*n*) indicates number of quadrat samples.

Category	Comparison (*n*)	x^2	df	*P*
Water depth (cm)	UP (90) vs. MW (90) vs. WE (90)	173.93	2	<0.001[a]
	UP (90) vs. MW (90)			<0.001[b]
	UP (90) vs. WE (90)			<0.001[b]
	MW (90) vs. WE (90)			<0.001[b]
Vegetation height (cm)	UP (90) vs. MW (90) vs. WE (90)	120.86	2	<0.001[a]
	UP (90) vs. MW (90)			<0.001[b]
	UP (90) vs. WE (90)			<0.001[b]
	MW (90) vs. WE (90)			<0.001[b]
Vegetation cover (%)	UP (90) vs. MW (90) vs. WE (90)	171.27	2	<0.001[a]
	UP (90) vs. MW (90)			<0.001[b]
	UP (90) vs. WE (90)			<0.001[b]
	MW (90) vs. WE (90)			<0.001[b]

[a] Kruskal-Wallis

[b] Mann-Whitney *U*



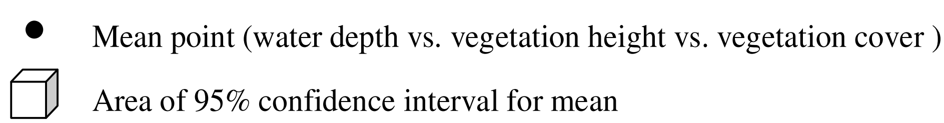


Fig. 14. Mean and 95% confidence interval for water depth, vegetation height and vegetation cover in three different landscape areas within the study area in 2000: upland areas, moderate-wet areas, and wet areas.

Table 7. Mean±SD of vegetation cover (%) for each vegetation group within a 0.25m x 0.25m quadrat plot in upland areas, moderate-wet areas, and wet areas of the study area in 2000.

Area	Mean ± SD (%)					Total vegetation cover mean±SD
	Carex spp.	Moss	Tussocks	Forbs	Shrubs	
Upland areas (*n*=90)	0	19.28±2.05	38.12±2.72	26.79±2.37	14.64±1.36	99.83±0.12 (%)
Modarate-wet areas (*n*=90)	22.71±3.36	18.8±2.52	17.94±2.78	9.28±1.97	14.34±2.37	83.22±2.95 (%)
Wet areas (*n*=90)	24.9±1.93	10.14±2.08	1.22±0.86	0	0.35±0.16	36.61±3.06 (%)

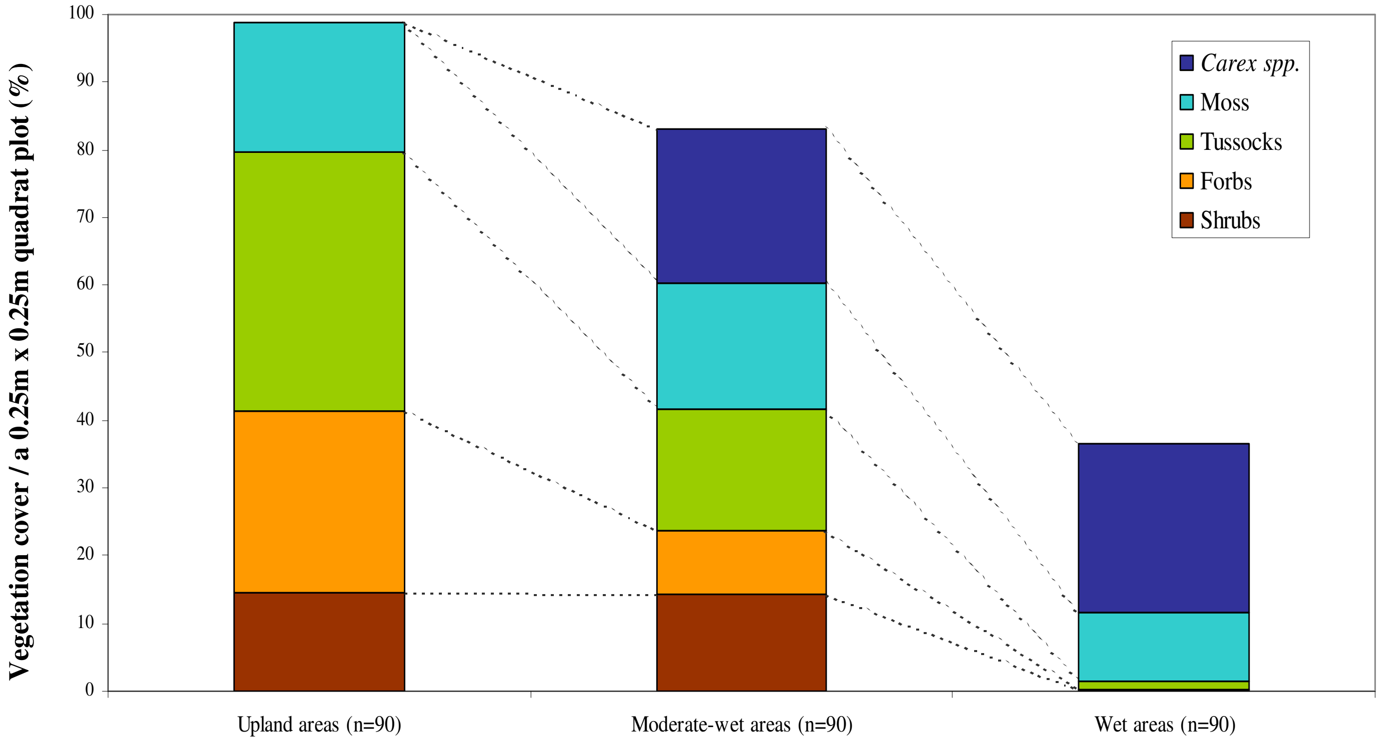


Fig. 15. Relative dominance (%) of ground cover for each vegetation type in upland areas, moderate-wet areas, and wet areas of the study area in 2000.

this vegetation cover was significantly ($P < 0.001$) higher than other areas (Table 8). Moderate-wet areas were covered with all vegetation types with total cover of 83% (Table 7). The most common vegetation group was *Carex* spp. (23%) in moderate-wet areas (Table 7); however, *Carex* spp. had a smaller ($P < 0.001$) portion of cover than wet areas (Table 8). Wet areas had a vegetation cover of 37% (Table 7, and Fig. 15). All vegetation types except forbs were seen in wet areas (Table 7). The most dominant vegetation groups were *Carex* spp. in wet areas (Fig. 15), and *Carex* spp. exhibited the greater ($P < 0.001$) vegetation cover than moderate-wet areas (Table 8).

Food abundance in upland, moderate-wet, and wet area

Small fishes <10 cm in length (e.g., ninespine sticklebacks) were found during cell samplings. The abundance of small fishes was significantly ($X^2 = 217.43$, df = 2, $P < 0.001$) different in upland, moderate-wet, and wet areas (Table 9). Expectably, small fishes occurred more in wet areas than other areas (Fig. 16).

Nests with eggs or chicks of six species of land-nesting birds [Pectoral Sandpiper (*Calidris melanotos*), Ruff, Northern Phalarope (*Phalaropus labatus*), Red Phalarope (*P. fulicarius*), Red-throated Pipit (*Anthus cervinus*), and Lapland Longspur (*Calcarious lapponicus*)], were found across the entire study area. Nests with eggs or nearly hatched chicks of Red-throated Pipits were recorded in a total of seven cells in upland areas. Nests with eggs or nearly hatched chicks of Pectoral Sandpipers, Ruffs, Northern Phalaropes, Red Phalaropes, or Lapland Longspurs occurred in a total of nine cells in moderate-wet areas. A nest (with eggs) of Red Phalarope was found in only one cell in a

Table 8. Comparisons of vegetation cover (%) in upland areas (UP), moderate-wet areas (MW), and wet areas (WE) of the study area in 2000. *P*-values were based on results of Kruskal-Wallis tests and Mann-Whitney *U* tests. (*n*) indicates number of quadrat samples.

Category	Comparison (*n*)	x^2	df	*P*
Carex spp. (%)	UP (90) vs. MW (90) vs. WE (90)	135.32	2	<0.001[a]
	UP (90) vs. MW (90)			<0.001[b]
	UP (90) vs. WE (90)			<0.001[b]
	MW (90) vs. WE (90)			<0.001[b]
Moss (%)	UP (90) vs. MW (90) vs. WE (90)	20.57	2	<0.001[a]
	UP (90) vs. MW (90)			0.213[b]
	UP (90) vs. WE (90)			<0.001[b]
	MW (90) vs. WE (90)			0.025[b]
Tussocks (%)	UP (90) vs. MW (90) vs. WE (90)	128.59	2	<0.001[a]
	UP (90) vs. MW (90)			<0.001[b]
	UP (90) vs. WE (90)			<0.001[b]
	MW (90) vs. WE (90)			<0.001[b]
Forbs (%)	UP (90) vs. MW (90) vs. WE (90)	138.18	2	<0.001[a]
	UP (90) vs. MW (90)			<0.001[b]
	UP (90) vs. WE (90)			<0.001[b]
	MW (90) vs. WE (90)			<0.001[b]
Shrubs (%)	UP (90) vs. MW (90) vs. WE (90)	83.03	2	<0.001[a]
	UP (90) vs. MW (90)			0.176[b]
	UP (90) vs. WE (90)			<0.001[b]
	MW (90) vs. WE (90)			<0.001[b]

[a] Kruskal-Wallis
[b] Mann-Whitney *U*

Table 9. Comparisons of food item occurrences in upland areas (UP), moderate-wet areas (MW), and wet areas (WE) of the study area in 2000. Food items were small fishes, small bird's nests (eggs and chicks), and insects and spiders. Each food item occurrence (or non-occurrence) was recorded within each cell in total 300 sample cells. One sample cell size was a 10m x 10m for small fish and small bird's nest (eggs and chicks) surveys and a 1m x 1m for an insect and spider survey.

		Number of sample cell			Chi-square test		
Food category	Location	Occur	Non-Occur	Comparison	x^2	df	*P*
Small fishes	UP	0	300	UP vs. MW vs. WE	217.43	2	<0.001
	MW	16	284	UP vs. MW	16.44	1	<0.001
	WE	105	195	UP vs. WE	127.34	1	<0.001
				MW vs. WE	82	1	<0.001
Small bird nests (eggs and chicks)	UP	7	293	UP vs. MW vs. WE	6.24	2	0.044
	MW	9	291	UP vs. MW	0.26	1	0.612
	WE	1	299	UP vs. WE	4.56	1	0.033
				MW vs. WE	6.52	1	0.011
Insects and spiders	UP	98	202	UP vs. MW vs. WE	41.29	2	<0.001
	MW	77	223	UP vs. MW	3.56	1	0.059
	WE	33	267	UP vs. WE	41.26	1	<0.001
				MW vs. WE	21.56	1	<0.001

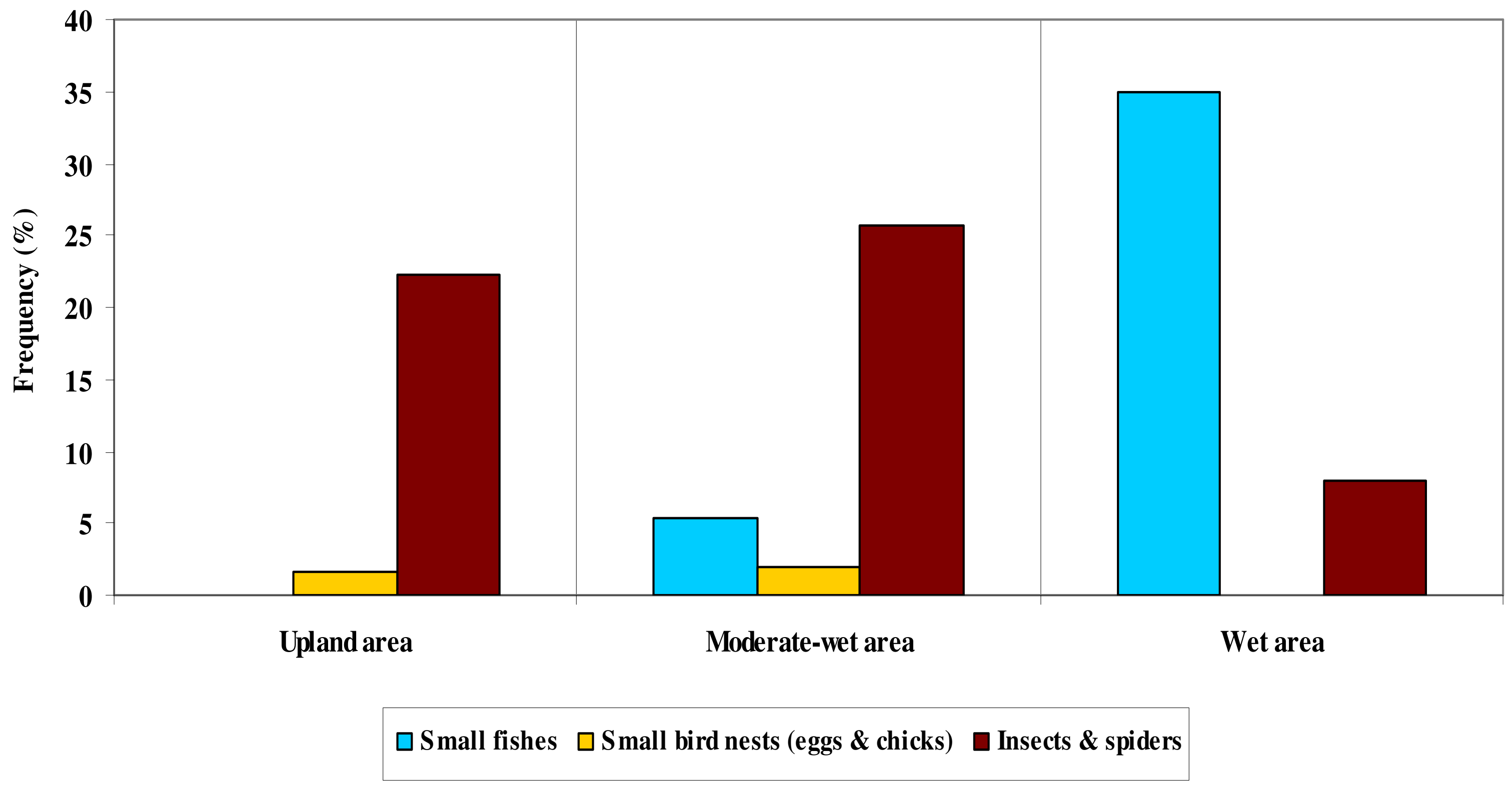


Fig. 16. Frequency of occurrence for small fishes, small bird nests (eggs & chicks), and insects & spiders within 300 sample cells in each upland, moderate-wet, and wet area of the study area in 2000. One sample cell size for small fishes and small bird nests (eggs & chicks) was a 10m x 10m area, and one sample cell size for insects & spiders was a 1m x 1m area.

wet area. Occurrences of small bird's nests (eggs or chicks) were significantly (X^2 = 6.24, df = 2, P = 0.044) different in upland, moderate-wet, and wet areas (Table 9); however, occurrences of small bird's nests (eggs or chicks) between upland areas and moderate-wet area were not significantly (X^2 = 0.26, df = 1, P = 0.612) different (Table 9). The abundance of small bird's eggs or chicks in wet areas was lower than in other areas (Fig. 16).

Several species of beetles, caterpillars or cocoons, crane flies, caddisflies, and spiders were found in the entire sample area. Mosquitoes were not considered for this survey because they were found in concentrations surrounding investigators. Insects and spiders were recorded in a total of 98 cells out of 300 cells in upland areas. Insects and spiders occurred in a total of 77 cells out of 300 cells in moderate-wet areas. Insects and spiders were found in 33 cells out of 300 cells in wet areas. Occurrences of insects or spiders were significantly (X^2 = 41.29, df = 2, P < 0.001) different in upland, moderate-wet, and wet areas (Table 9); however, occurrences of insects or spiders between upland areas and moderate-wet areas were not significantly (X^2 = 3.56, df = 1, P = 0.059) different (Table 9). The abundance of insects or spiders in wet areas was lower than in other areas (Fig. 16).

DISCUSSION

The study results suggested that Lesser Sandhill and Siberian cranes used different habitat types for foraging in the study area. Lesser Sandhill Cranes used moderate-wet areas during the June–July 2000, and Siberian Cranes spent most of their breeding season in wet areas. The different habitat-use patterns of the species may be due to the availability of their different food sources. Similarly, Chavez-Ramirez (1996) confirmed that birds spend most of their foraging time in areas that yield the highest food intake rates.

The results of microhabitat evaluations suggested that characteristics of moderate-wet areas, used regularly by Lesser Sandhill Cranes, included vegetation characteristics of upland and wet areas. The existence of polygon wedge-crack pools or channels in moderate wet area formed a mean depth of three cm water and a mean height of 14 cm with a variety of vegetation types and covers. These complex microhabitat characteristics of moderate wet areas may provide main food resources of Lesser Sandhill Cranes.

I found that small bird eggs or chicks in moderate-wet areas were more abundant and with a greater variety of food items than other areas. Insects or spiders were also more abundant in moderate-wet areas greater than in wet areas. Therefore, Lesser Sandhill Cranes use of moderate-wet areas provided access to terrestrial food items, such as bird eggs or chicks and insects or spiders in moderate-wet areas, than aquatic foods (small fishes). Lesser Sandhill Cranes were seen pecking and destroying nests of Lapland Longspurs (and several other small ground-nesting birds) and possibly chasing newly hatched shorebirds (T. Watanabe pers. obsev.). Reed (1988) reported that Lesser Sandhill Cranes ate chicks of small birds on Banks Island. Lesser Sandhill Cranes also were observed feeding on eggs and young of Snow Geese (*Chen caerulescens*), Willow Ptarmigan, and collared lemmings in the western shore of Hudson Bay by Harvey et al.

(1968). Boise (1977) collected gizzard contents from four Lesser Sandhill Cranes in Alaska in summer 1976 and found hair, bones, and teeth of unidentified microtine, flying insects as well as fruit and seeds of crowberries (*Empetrum nigrum*). My observations and literature suggested that Lesser Sandhill Cranes ate terrestrial foods and plants whenever available in moderate-wet areas.

Overall, Lesser Sandhill Cranes used moderate-wet areas more during the research period; however, as Walkinshaw (1949, 1973) mentioned, Lesser Sandhill Crane are omnivorous and habits very considerably with season and what foods are available at the time. Similar to Boise' (1977) description of foraging habits of Lesser Sandhill Cranes in Alaska, I also observed that habitat-use patterns of Lesser Sandhill Cranes changed during their breeding season. In June, when the ground was still covered by snow, Lesser Sandhill Cranes were observed in upland areas. Perfilyev (1965) mentioned that the most available foods at the beginning of the breeding season on the snow covered tundra were lemmings and voles. Lesser Sandhill Cranes were observed constantly digging at the bases of hummocks in upland areas. I believe that before aquatic or other terrestrial foods were available, such as small bird eggs and insects, Lesser Sandhill Cranes foraged on lemmings and voles, and plants, including roots, rhizomes, sprouts of tussocks and forbs, and fruit remains from last season in snow free upland areas. Lesser Sandhill Cranes frequently were observed in wet areas, specifically during 11 June and 16 June 2000. There were clumped small fishes in wet areas during this time period, when ice melting at the edge of lakes had created pools in low basins (T. Watanabe pers. observ.). Therefore, I assumed that they were consuming clumped small fishes in low basins. It is possible terrestrial food items had not been available yet in this time period, Lesser Sandhill Cranes used wet areas and were observed consuming an aquatic food item (e.g., small fishes). It appears habitat-use patterns of Lesser Sandhill Cranes changed during the breeding period in response to what food was available at the time. Furthermore, Lesser Sandhill Cranes used exclusively moderate-wet areas after terrestrial foods became available in the areas.

I found that Siberian Cranes were regularly observed foraging in wet areas, where *Carex* spp. and small fishes were most abundant, throughout both months. Characteristics of wet areas, which Siberian Crane used frequently during the study period, were significantly different from other landscape areas as well. Water depths of wet areas, primary shallow-water aquatic habitats were expectedly higher than other areas (e.g. moderate-wet areas). The average vegetation cover in wet areas was 37%; much lower than other areas. The study result showed that 25% of *Carex* spp. covers in wet areas was significantly higher than other areas. *Carex* spp. occupied more than 68% of the total 37% vegetation cover of wet areas. This result concurred with the report of Flint and Kistchinski (1981) that Siberian Cranes feed mainly on the roots, rhizomes, and sprouts of sedges in tundra. Meine and Archibald (1996) reported that the diet of Siberian Cranes on the breeding grounds consisted of plants, including roots, rhizomes, sprouts of sedges, seeds, and berries, as well as fish. Wet areas produced suitable food sources for Siberian Crane and provided the necessary conditions for Siberian Cranes in the tundra.

Further, I found that food abundances of small bird eggs or chicks and insects or spiders in wet areas were significantly less than other areas; however, small fishes were the prey observed in dominate wet areas. Siberian Cranes spent most of the time in wet areas. I frequently observed that Siberian Cranes chasing small fishes or constantly pecking bottoms of sedge grasses in the wet areas. They may consume more aquatic food (small fishes and roots of sedge plants) in wet areas, than terrestrial food items such as bird eggs or chicks and insects or spiders on breeding ground.

Sauey (1985) described Siberian Crane diets and mentioned that animal foods were especially important at the beginning of the breeding season and during the chick-rearing period. Siberian Cranes were observed several days in moderate-wet and upland areas during the study period. These excursions into moderate-wet and upland areas suggest that Siberian Cranes were consuming terrestrial food items.

At the beginning of the breeding season on the tundra, the most available foods are lemmings and voles (Perfilyev 1965). I observed Siberian Cranes constantly digging at the bases of hummocks in upland areas. I believe that before aquatic foods were available, early arrival Siberian Cranes also foraged for lemmings and voles as much as plant roots, rhizomes, sprouts of tussocks and forbs, and fruit remains in snow-free upland areas.

If food competition occurred between Lesser Sandhill and Siberian cranes, it might be possible it happens during late May and early June periods. However, this time period is short and widely spaced upland areas were still available. Lesser Sandhill Cranes also used wet areas during short periods of mid-June, when clumped small fishes and aquatic plants were widely available in wet areas. I did not observe any interactions between Lesser Sandhill and Siberian cranes during those periods.

Lesser Sandhill Cranes may mostly depend on terrestrial foods in moderate-wet areas, and Siberian Cranes preferred aquatic foods in wet areas during the breeding season. Overlap of habitat use of Lesser Sandhill and Siberian cranes rarely happened during this study, and different food requirements may allow their coexistence in the Siberian tundra.

CHAPTER VI

TIME ACTIVITY BUDGETS

RESULTS

Observations were conducted for three Lesser Sandhill Crane pairs (37 sessions) and for three Siberian Crane pairs (39 sessions), representing approximately 19 and 20 hours, respectively of total time activities budgets.

Locomotion comprised 35% and 16% of all behavioral activities of Lesser Sandhill and Siberian cranes, respectively, (Fig. 17). Frequency of locomotion was significantly ($P = 0.00$) different between Lesser Sandhill and Siberian cranes. Lesser Sandhill Cranes spent more than twice as much time in locomotory activities than Siberian Cranes. Monthly pooled data showed that Lesser Sandhill Cranes spent different ($P = 0.003$) amounts of time in locomotion between June and July (Fig. 18). There was a positive correlation (Kendall's tau = 0.31, $P = 0.008$) between 10 day periods and occurrences of locomotory behaviors of Lesser Sandhill Cranes (Fig. 19). Lesser Sandhill Cranes gradually spent more time in locomotion toward late July. Between June and July, Siberian Cranes spent different ($P = 0.019$) amounts of time in locomotion (Fig. 18). There was a positive correlation (Kendall's tau = 0.271, $P = 0.017$) between 10 day periods and occurrences of locomotory behaviors of Siberian Cranes (Fig. 19). Locomotory activities of Siberian Cranes gradually increased toward late July.

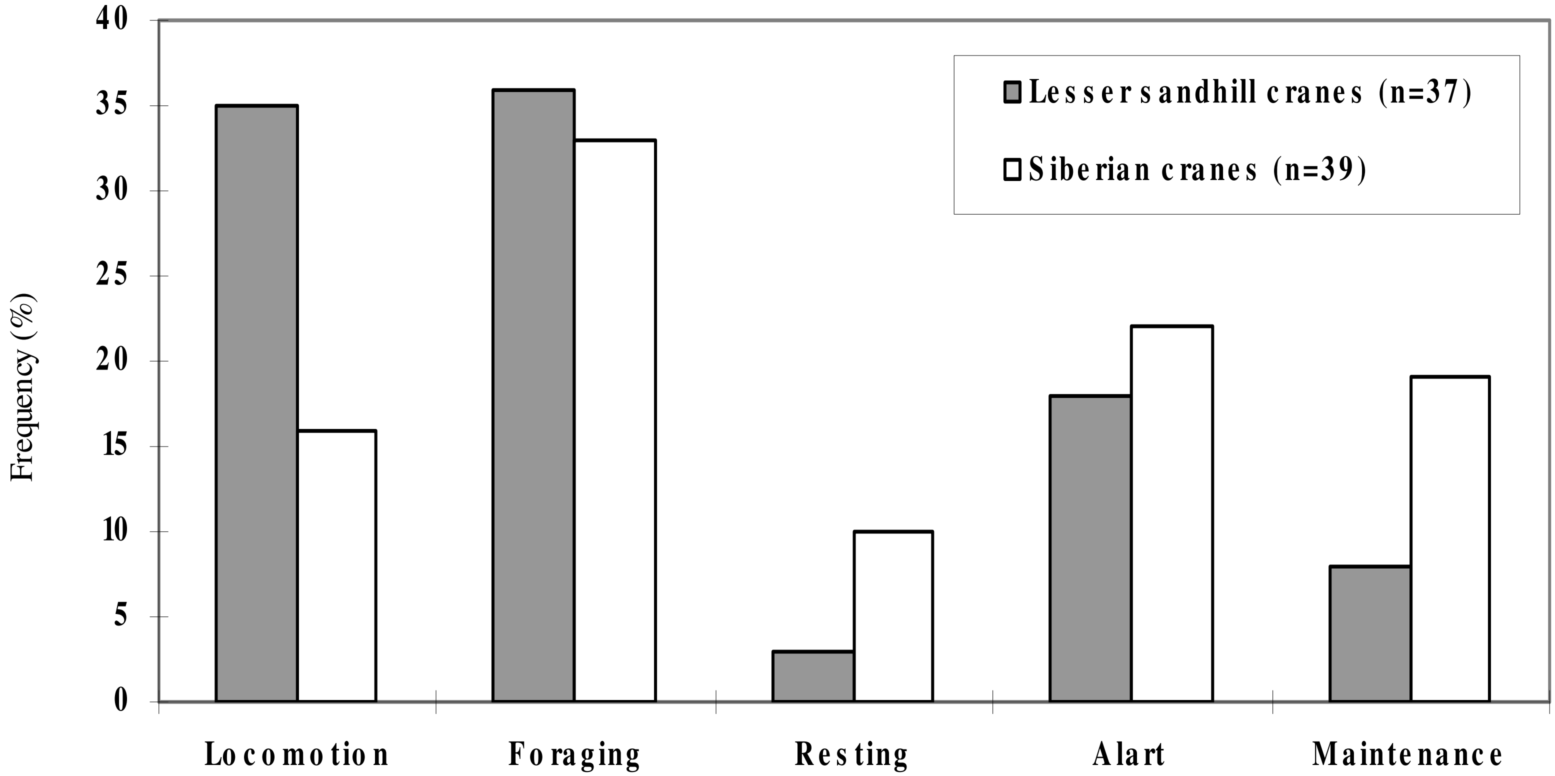


Fig. 17. Frequency of occurrence for different behaviors of Lesser Sandhill Cranes and Siberian Cranes in the study area in 2000. (n) = Number of 30 minute observation sessions.

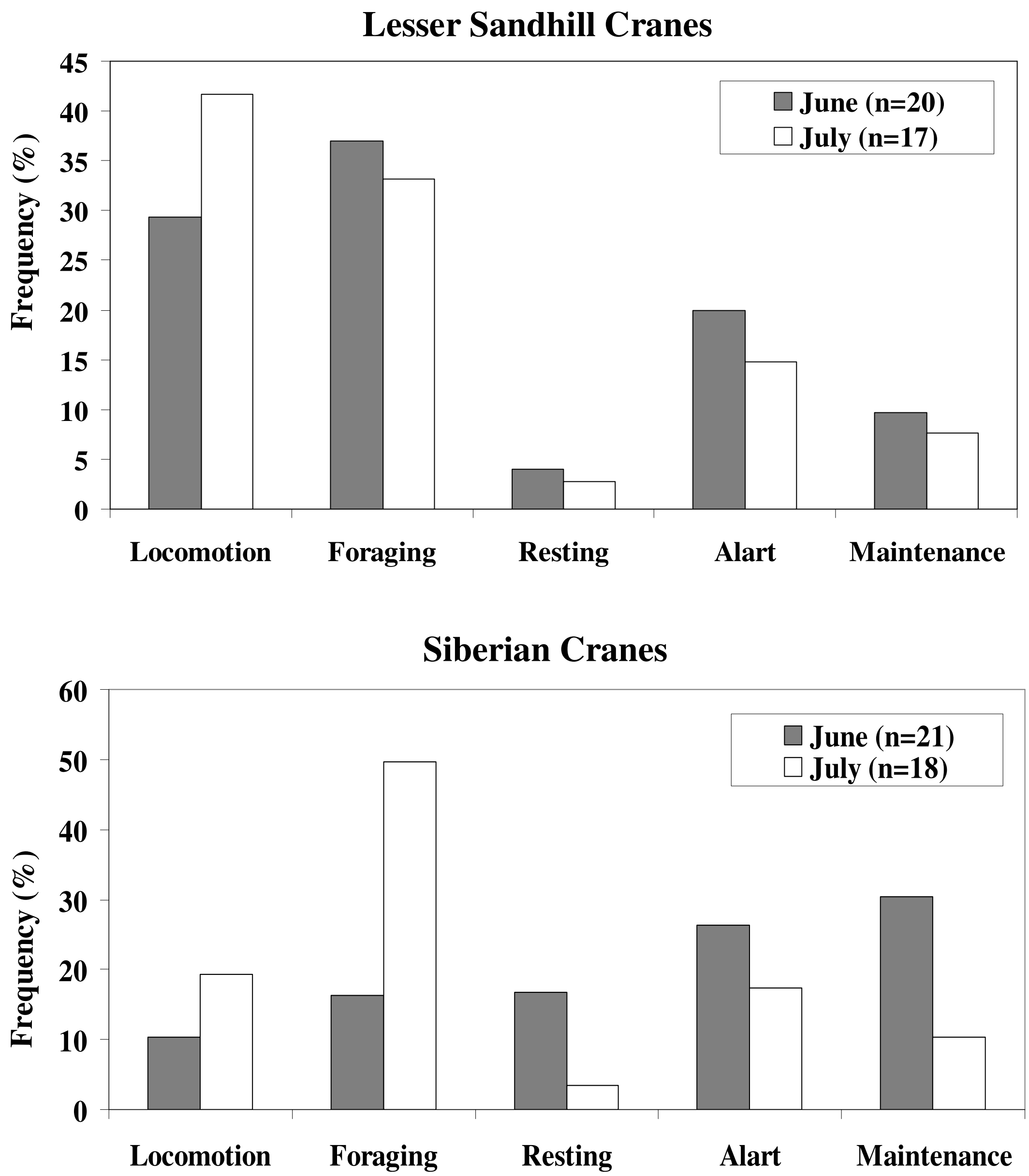


Fig. 18. Changes in frequencies of different behaviors of Lesser Sandhill Cranes and Siberian Cranes in the study area in June and July 2000. (n) = Number of 30 minute observation sessions.

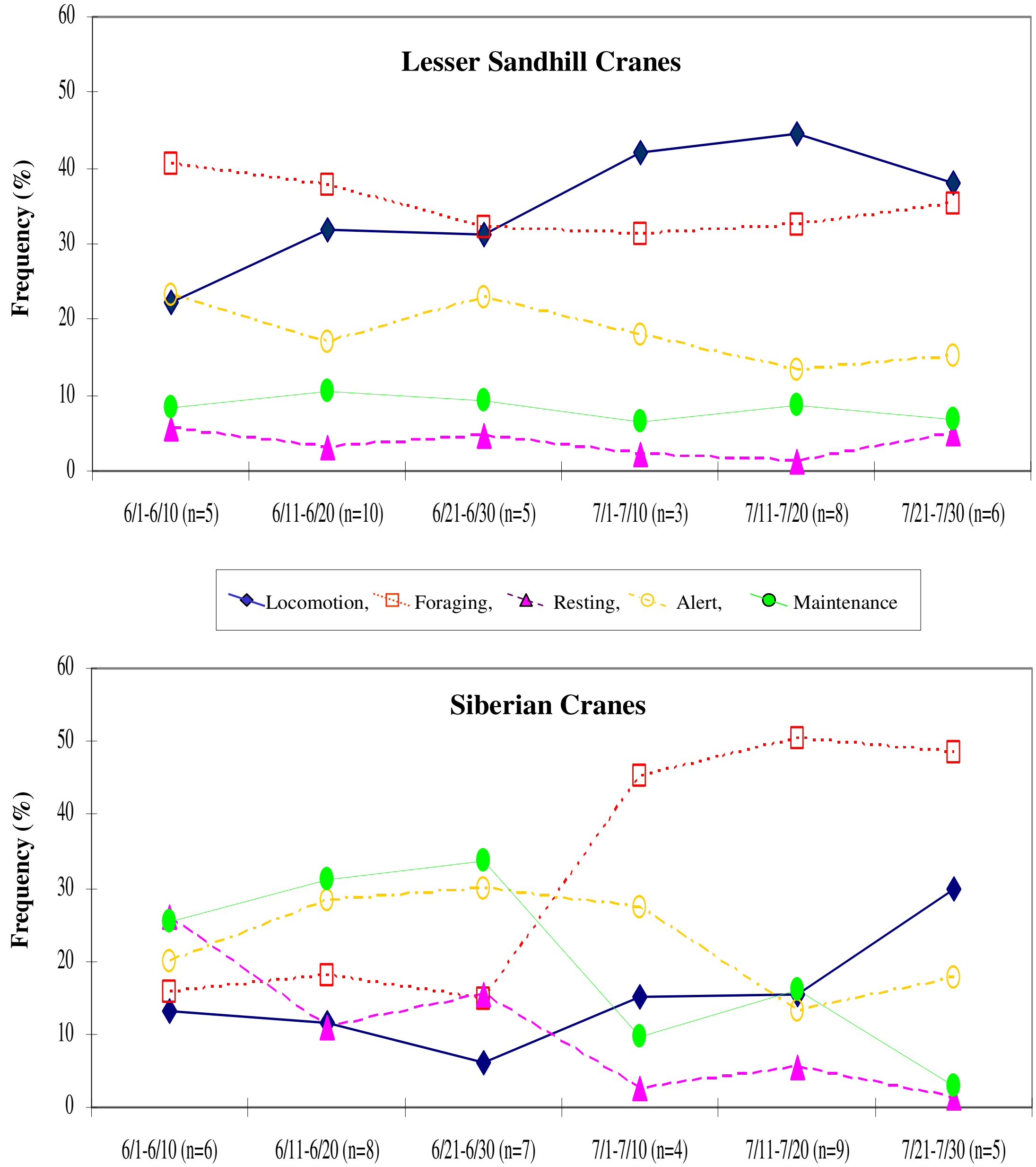


Fig. 19. Changes in frequencies of different behaviors of Lesser Sandhill Cranes and Siberian Cranes in 10 day intervals from 1 June to 30 July 2000. (n) = Number of 30 minute observation sessions.

Lesser Sandhill and Siberian cranes spent the same amount of time in foraging activities. Foraging comprised 36% and 33% of all behavioral activities of Lesser Sandhill and Siberian cranes, respectively (Fig. 17). Frequency of foraging behaviors between Lesser Sandhill and Siberian cranes was not significantly ($P = 0.601$) different. Lesser Sandhill Cranes did not show significant ($P = 652$) differences in time spent foraging between June and July (Fig. 18). There was no correlation (Kendall's tau = 0.001, $P = 0.991$) between 10-day periods and occurrences of foraging behaviors of Lesser Sandhill Cranes (Fig. 19). Lesser Sandhill Cranes spent the same amount of time in foraging activities throughout the breeding season. Monthly pooled data showed that Siberian Cranes spent different ($P < 0.001$) amount of time in foraging activities between June and July (Fig. 18). Siberian Cranes showed a positive correlation (Kendall's tau = 0.532, $P = 0.001$) between 10 day periods and occurrences of foraging behaviors increasing noticeably in July (Fig. 19).

Resting comprised 3% and 10% of all behavioral activities for Lesser Sandhill and Siberian cranes, respectively (Fig. 17). Frequency of resting between Lesser Sandhill and Siberian cranes differed significantly ($P = 0.005$) with Siberian Cranes spending more time resting than Lesser Sandhill Cranes. There was no significant ($P = 0.541$) difference in frequency of resting between June and July in Lesser Sandhill Cranes (Fig. 18). In addition, there was no correlation (Kendall's tau = -0.143, $P = 0.252$) between 10-day periods and occurrences of resting of Lesser Sandhill Cranes (Fig. 19). Lesser Sandhill Cranes spent the same amount of time resting between June and July, while Siberian Cranes spent different ($P < 0.001$) amounts of time in resting (Fig. 18). There was a significantly negative correlation (Kendall's tau = -0.538, *P* = 0.001) between 10-day periods and occurrences of resting behaviors of Siberian Cranes (Fig. 19) with resting behaviors of Siberian Cranes gradually decreasing toward late July.

Alert behavior comprised 18% and 22% of all behavioral activities for Lesser Sandhill and Siberian cranes, respectively (Fig. 17). Frequency of alert behaviors was not significantly (*P* = 0.075) different between Lesser Sandhill and Siberian cranes. Between June and July, Lesser Sandhill Cranes did not show significant (*P* = 0.269) differences in frequency of alert activities (Fig. 18). There was no correlation (Kendall's tau = -0.122, *P* = 0.302) between 10-day periods and occurrences of alert behaviors of Lesser Sandhill Cranes (Fig. 19). Lesser Sandhill Cranes spent the same amount of time being alert during the two-month period. Between June and July, Siberian Cranes spent different (*P* = 0.006) amounts of time in alert behaviors (Fig. 18), with alert behavior gradually increasing toward late July. There was a significantly (Kendall's tau = -0.225, *P* = 0.048) negative correlation between 10 day periods and occurrences of alert of Siberian Cranes (Fig. 19).

Maintenance behaviors comprised 8% and 19% of all activities of Lesser Sandhill and Siberian cranes, respectively (Fig. 17). Frequency of maintenance activities between Lesser Sandhill and Siberian cranes was significantly (*P* = 0.002) different with Siberian Cranes spending more time in maintenance activities than Lesser Sandhill Cranes. Between June and July, Lesser Sandhill Cranes did not show any significant (*P* = 0.487) differences in amount of time spend in maintenance activities (Fig. 18). There was no correlation Kendall's tau = -0.2, *P* = 0.094) between 10-day periods and occurrences of maintenance activities of Lesser Sandhill Cranes (Fig. 19). Lesser Sandhill Cranes spent the same amount of time for maintenance activities from early June to late July (Fig. 19). Monthly pooled data showed that Siberian Cranes spent different ($P < 0.001$) amount of time in maintenance activities between June and July (Fig. 18) with resting behaviors gradually decreasing toward late July. There was a significant (Kendall's tau = -0.478, $P = 0.001$) negative correlation between 10-day periods and occurrences of maintenance behaviors of Siberian Cranes (Fig. 19).

DISCUSSION

The time budgets for each behavioral activity showed different patterns for Lesser Sandhill and Siberian cranes as Lesser Sandhill Cranes spent more time in locomoter activities than the Siberian Cranes. The Lesser Sandhill Cranes nested on moderate-wet (polygon) areas, but foraging occurred sometimes on wet areas during their incubation periods in June (Chapter V). Lesser Sandhill Cranes were observed to switch their incubation duties. For example, one individual Lesser Sandhill Crane flew or walked into foraging areas far from its nest. Lesser Sandhill Cranes were well camouflaged by their plumage feather coloration and their nesting environment in the uneven landscape grounds of moderate-wet (polygon) areas. In one instance, a Lesser Sandhill Crane that was incubating on its nest, was not seen until the incubating crane flushed less than 10-m away.

In contrast, Siberian Cranes nested on the wet areas in wide-open flat areas (Chapter IV). The white feathers of Siberian Cranes were easily located from long distances. During incubation periods for the month of June, Siberian Cranes stayed near their nests (T. Watanabe pers. observ.). In June periods, one individual Siberian Crane was observed standing between 2–5 m from another crane, which was incubating its eggs on the nest. The individual crane standing near its nest performed primarily alert and maintenance activities. Siberian Crane mates appeared to stay closer to its nest and protected the incubating mate and eggs from predators, such as arctic foxes (Perfilyev 1965).

My observations also suggested that even after the incubation period in June, Lesser Sandhill Cranes were more mobile than Siberian Cranes. Lesser Sandhill Cranes spent most of their time in locomotion and foraging on the breeding grounds. Together, locomotion and foraging behavior was more than 70% of their total behavioral activities (Fig. 17). In general, I observed Lesser Sandhill Cranes constantly moving and foraging over a wide range of moderate-wet areas, where terrestrial foods were scattered. As a consequence, resting behaviors of Lesser Sandhill Cranes accounted for only 3% of the total behavioral activity budget.

The results showed that time budgets of locomotor activities of Lesser Sandhill Cranes changed over time. Lesser Sandhill Cranes gradually spent more time in locomotion toward late July (Fig. 19). Lesser Sandhill Cranes were observed spending periods of time in wet areas during the middle of June consuming small fishes that were concentrated in the small wet areas near lakes (Chapter V). I observed that Lesser Sandhill Cranes frequently foraged for clumped resources (e.g., aquatic foods) in the small spaces of wet areas, but seldom walking foraging. After the end of June, Lesser

Sandhill Cranes spent more time in moderate-wet areas and foraged on more dispersed resources (e.g., terrestrial foods) over a wide-ranging area. This may explain seasonal changes of locomotion activities. Other behavioral activities such as foraging, resting, alert, and maintenance did not show any changes of time budgets of Lesser Sandhill Cranes throughout the breeding season.

Tacha et al. (1987) reported that mid-continent Sandhill Cranes, including Lesser Sandhill Cranes, spent considerable time in locomotor activities, including flying, as 16.9%, 9%, 5.6%, and 5.6% of total diurnal activities during migration in Texas, Nebraska, Saskatchewan, and Alaska, respectively. The present study showed the locomotor activity of Lesser Sandhill Cranes in the study area was 35%, and this time budget was higher than during any migration periods described by Tacha et al. (1987). Time budgets for foraging activities include food searching, gleaning, and probing of mid-continent Sandhill Cranes were 39.5%, 52.2%, 63.7%, and 51.8% of total diurnal activities during migration in Texas, Nebraska, Saskatchewan, and Alaska, respectively (Tacha et al. 1987). The foraging activity of Lesser Sandhill Cranes in this study was 36%, lower than during migration periods. Harvested grain fields (corn, wheat, and barley) were the principal habitat types used by Sandhill Cranes including Lesser Sandhill Cranes during spring migration in Nebraska, Saskatchewan, and Alaska, respectively (Iverson et al. 1987). Wheat, corn, sorghum, and milo were major food items whenever available on the wintering grounds (Tacha et al. 1992). During migration, Lesser Sandhill Cranes consumed cultivated grains in agricultural fields; however, in the low arctic tundra, the Lesser Sandhill Cranes must search for food over wide ranges of moderate-wet foraging areas. This environmental difference may require an increase in the amount of movement required, while foraging activities decrease in breeding grounds.

Locomotor activities of Siberian Cranes were recorded only when the individual crane was searching for food around the nest or chasing conspecific or heterospecific cranes, which had approached within approximately 1 km of the nest. Each locomotor activity occurred over short-time periods. The Siberian Cranes used wet areas where small fishes and roots of sedge grasses were clumped and abundant (Chapter V). The Siberian Cranes consumed aquatic foods without the need for extended locomotion in the wet areas.

After the Siberian Crane eggs hatched in early July, the Siberian Cranes spent more time foraging (Fig. 18) and consumed aquatic foods such as small fishes and roots of sedge grasses in the wet areas. The locomotion time periods of Siberian Cranes increased slightly as the foraging area around nests and young expanded. Because foraging and locomotor activities increased toward the end of July, resting, alert, and maintenance behaviors were observed less often during observations.

This study has shown that the Lesser Sandhill and Siberian cranes both spent the same amount of their total behavioral time budget on foraging activities; though, the two species foraged in different habitat types. The time spent on alert was not significantly different between Lesser Sandhill and Siberian cranes as well.

Cranes frequently showed alert behaviors when conspecifics or heterospecifics flew, walked, or called around them; however, attentions to conspecific cranes were greater than to heterospecific. (Chapter IV). Alert behaviors were observed when arctic foxes or reindeer walked close by. Neither the Lesser Sandhill Cranes nor the Siberian Cranes showed any flight behavior when large mammals were near. Both the Lesser Sandhill and Siberian cranes showed aggression behavior when arctic foxes or caribous approached their nests and even chased or charged them.

I predicted that both Lesser Sandhill and Siberian cranes would spend more time in alert behaviors during incubation period in June. The study showed that Lesser Sandhill Cranes did not show significant differences in frequency of alert activities between June and July. Lesser Sandhill Cranes foraged far from their nest sites while another mate was incubating. The incubating bird was well camouflaged by feathers in the moderate-wet (polygon) environment. Lesser Sandhill Cranes might not require higher alert during incubation periods. In contrast, Siberian Cranes spent more amount of time in alert behavior in June than in July. The white feathers of Siberian Cranes were easily located from long distances, and Siberian Cranes required higher alert and attentiveness to protect the incubating mate and their eggs from predators in June. After the incubation periods ended and the mobility of Siberian Cranes, reduced the potential dangers of predators.

CHAPTER VII

CONCLUSION

The results of this study showed that Lesser Sandhill and Siberian cranes have different characteristics of their nesting habitat types, habitat-use patterns, and time activity budgets in Eastern Siberia. These differences, in part, may allow these two species to coexist in sympatry.

Nests of Lesser Sandhill and Siberian cranes were significantly farther from conspecific nests than to nests of heterospecifics. This suggests that both species were more territorial towards conspecific individuals than toward heterospecific species.

Lesser Sandhill Cranes used moderate-wet (polygon) areas as their nest sites. In contrast, Siberian Cranes nested on wet areas with higher water levels and taller *Carex* spp. vegetation than did Lesser Sandhill Cranes. Habitat structure between the Siberian Cranes and the Lesser Sandhill Cranes were different. Siberian Cranes required larger wet spatial areas for nesting, and Lesser Sandhill Cranes could make nests on relatively smaller spaces on moderate-wet (polygon) areas.

Lesser Sandhill and Siberian cranes used different habitats for foraging. Lesser Sandhill Cranes were observed most of the time on moderate-wet areas, and Siberian Cranes spent most of their time in wet areas. The differences in habitat-use patterns may be due to the availability and preferences of different food sources. The abundance of small bird eggs or chicks and insects or spiders in wet areas was significantly less than other areas; however, small fish abundance in the wet areas was much higher than in the moderate-wet areas. Lesser Sandhill Cranes depended on terrestrial foods, and Siberian Cranes preferred aquatic foods. Overlap of habitat use of Lesser Sandhill and Siberian cranes rarely happened; however, different food availability might allow their coexistence in the Siberian tundra.

The time-activity budgets showed different patterns for Lesser Sandhill and Siberian cranes. The Lesser Sandhill Cranes exhibited greater locomotory behaviors than the Siberian Cranes, with the Lesser Sandhill Cranes constantly moving and foraging on a wide range of moderate-wet areas. In contrast, Siberian Cranes used the wet areas, where small fishes and roots of sedge grasses were concentrated and abundant. Siberian Cranes could consume many clumped aquatic foods without the need for long periods of locomotion in the wet areas.

The Lesser Sandhill and Siberian cranes both spent similar amounts of time on foraging activities, though the two species foraged in different habitat types. Time spent in alert behaviors was not significantly different between the Lesser Sandhill and Siberian cranes, as well.

I observed that cranes showed frequent alert behaviors when conspecific or heterospecific cranes flew, walked, or called near them. When another crane approached too closely, alert behaviors turned to aggressive chases; however, attention to conspecific cranes was more common than to heterospecific cranes. I often observed a pair of Lesser Sandhill Cranes chase another Lesser Sandhill Crane, but I did not observe Lesser Sandhill Cranes chase Siberian Cranes in the study area. I observed Lesser Sandhill Cranes foraged approximately 1 km away from a Siberian Crane nest, although Lesser

Sandhill Cranes were chased away when approached less than 1 km from a Siberian Crane nest. A pair of Siberian Cranes chased other Siberian Cranes, even 2 km away from their nest. It is clear that both species were more aggressive toward conspecific individuals than toward heterospecific species.

Lesser Sandhill and Siberian cranes in Eastern Siberia coexisted within the same landscape. Each crane species used different habitat types for nesting, foraging and both were more aggressive toward conspecific species than toward heterospecifics. Though, the population of Lesser Sandhill Cranes in the study area has a potential of increasing in the future, both the Lesser Sandhill and Siberian cranes appear to be able to share the same general area.

FUTURE RESEARCH CONSIDERATIONS

Nesting densities of Lesser Sandhill and Siberian cranes, and habitat types of the study area may change from year to year. Continued field study requires complete understanding of both Lesser Sandhill and Siberian cranes' habitats and their relationships. The population of Lesser Sandhill Cranes in the study area has a potential of increasing in the future and it will be important to monitor continuously Lesser Sandhill Crane populations in the area.

Once the population of Lesser Sandhill Crane reaches its carrying capacity in the area, the population may expand continuously westward (e.g., Lena River Delta regions) without major impacts on the Siberian Crane population. However, there is a possibility of food competition between Lesser Sandhill and Siberian cranes during late May and early June periods if Lesser Sandhill Crane population density becomes too high. Continued observation will enable crane ecologists to compare time activity budget patterns with the baseline data from this study. Major changes in alert behaviors and time spent foraging will be indicators of population stresses caused by interspecific competition.

To better understand both Lesser Sandhill and Siberian cranes' nesting habitats and their relationships, greater information on characteristics of Siberian Crane nesting habitat types, habitat-use patterns, and time activity budgets are also needed in breeding regions without competition with Lesser Sandhill Cranes.

Because of the location of the nest search area and characteristics of cranes, only three nests of each species were found in the nest search area. To increase sample sizes of Siberian Crane nests, the nest search area should be greatly extended. To find more Lesser Sandhill Crane nests, the moderate-wet (polygon) areas should be targeted in a much larger geographical area.

A helicopter could be used for transportation and aerial surveys to extend the study areas in the Siberian tundra. In this study, a helicopter was available for only limited times because of lack of fuel and mechanical difficulties.

To define accurate home ranges of Lesser Sandhill and Siberian cranes in the study area, telemetry research may be considered in the future. In this study, the use of satellite platform transmitter terminals (PTT's) on Lesser Sandhill Cranes was planned to define crane migration routes to wintering grounds; however, because of lack of helicopter support, no Lesser Sandhill Cranes in the study area could be captured.

In this study, a polygon area was considered a moderate-wet area. The study area contained a large moderate-wet area, which could be divided into two habitat types, such as low-centered polygons and high-centered polygons. In the future, the two habitat types should be considered separately.

The observer must be aware of difficulties of crane observations. Behavioral observation of cranes in arctic tundra was a great challenge for investigators. The weather in the arctic tundra region changed quickly and dramatically. Often during an observation session, thick fogs or low clouds covered both the crane and observer unexpectedly and interfered with behavioral observations. Lightning strikes were a concern during the observation sessions due to the vast, treeless expanses of the arctic tundra.

Further efforts to locate the breeding grounds of the western Siberian Crane population are needed to identify possible breeding grounds with correlating information on habitat characteristics using GIS technology (Meine and Archibald 1996). This study may contribute to conservation efforts to locate the breeding grounds of the Western population of Siberian Cranes and improve management for the endangered Siberian Cranes in the world.

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