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Channel habitat features that characterize roost sites selected by sandhill cranes along the Platte River were described during spring 1989. They selected water depths of 1-13 cm, channel widths of 100-200 m, and areas relatively isolated from human disturbance. Criteria for assessing suitability of roost sites were suggested.

ROOSTING ACTIVITY AND SITE SELECTION OF SANDHILL CRANES ALONG THE PLATTE RIVER, NEBRASKA

by

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CHAPTER I

INTRODUCTION

Water development projects in the western United States have impounded much of the natural water flow and diverted it for irrigation and other consumptive uses (Ohmart et al. 1977; Johnson 1978). As flows in western rivers have diminished during this century, numerous conflicts have arisen (Krapu et al. 1982). Additional water development projects are now being proposed that raise concerns over remaining instream flows. The diversion of rivers by man has impacted migratory bird populations in many areas, but few have been as significant as in the Platte River Basin (U.S. Fish and Wildlife Service 1981). The Big Bend Reach of the Platte River in Nebraska is an area of importance to numerous species of migratory birds of the Central Flyway (U.S. Fish and Wildlife Service 1981). This area is an important stopover area for most of the midcontinent population of sandhill cranes (Grus canadensis) which roost in the river and feed in nearby corn fields (Krapu et al. 1982; Krapu 1987). The endangered whooping crane (G. americana) also uses the area during migration and the threatened bald eagle (Haliaeetus leucocephalus) is a common winter resident (U.S. Fish and Wildlife Service 1981). The area is also important habitat for the endangered interior population of least tern (Sterna antillarum) and the threatened piping plover (Charadrius melodus), both of which nest along the Platte River (U.S. Fish and Wildlife Service 1981, 1988; Sidle et al. 1988).

WATER DEVELOPMENT -- A HISTORICAL PERSPECTIVE. Within the last century, water development along the Platte River has had a major impact on discharge. Approximately 70% of the discharge is diverted before reaching the Big Bend Reach (Kroonemeyer 1978; Williams 1978). Annual discharge of the Platte River near Overton, Nebraska, has dwindled from 3,200 million m^3 less than a century ago to 990 million m^3 during the last decade (Missouri River Basin Commission 1975).

Major changes in the hydrograph of the Platte River have occurred as a result of the construction of dams on the North Platte River between 1909 and 1961 (Krapu 1978; Krapu et al. 1982). Reservoirs built to impound water for irrigation purposes include Pathfinder Reservoir (constructed in 1909), Guernsey Reservoir (1927), Alcova Reservoir (1938), Seminoe Reservoir (1939), Lake McConaughy (1941), Kortes Reservoir (1950), Glendo Reservoir (1957), and Greyrocks Reservoir (1961) (Missouri River Basin Commission 1975). The total storage capacity for these reservoirs is over 6,200 million m^3, while several smaller reservoirs on tributaries raise the overall storage capacity to 6,700 million m^3. Reservoirs along the South Platte River account for another 1,600 million m^3 of storage capacity (Krapu et al. 1982). As a result of these impoundments, peak flows during spring in the North Platte (1957-1970) have declined 86% from the pre-reservoir period (1895-1909) (Currier et al. 1985).

A primary change resulting from reduced annual discharge, as well as the loss of high spring flows, has been the shrinkage of channel width by as much as 90% in some areas (Williams 1978). The most significant changes have occurred in a 365-km reach between Minatare and Overton, Nebraska, and a 115-km reach between Overton and Grand Island, Nebraska. Williams (1978) found that by 1969 the Minatare to Overton reach was 0.1-0.2 times as wide as in 1865, while the Overton to Grand Island reach was 0.6 - 0.7 as wide. Krapu et al. (1982) found that the width of unobstructed channel for the reach between the Tri County Dam (near North Platte) and Overton averaged about 50 m, while the channel width from Overton to Kearney was 142 m. This is contrasted by a Union Pacific Railroad survey in 1866 that reported the channel width from Kearney to North Platte to have been 1,200 to 2,000 m (Williams 1978).

ENCROACHMENT OF WOODY VEGETATION. Concurrent with reduced discharge and channel shrinkage, the encroachment of woody vegetation has been a factor in contributing to the changes in habitat for migratory birds along the Platte River during the past century (Frith 1974; U.S. Fish and Wildlife Service, 1981). Explorers along the Platte River during the 19th Century described a wide channel and nearly treeless riparian zone (Williams 1978; Eschner et al. 1981). However, during the past century, woody vegetation has developed across much of the river channel. The initial species to invade the channel have been willow (*Salix* spp.) and cottonwood (*Populus deltoides*), followed by numerous other species (Currier 1982; Krapu et al. 1982). Presently, riparian woodlands form a broad band of forested land from Kingsley Dam to Grand Island (Frith 1974; U.S. Fish and Wildlife Service 1981; Currier 1982).

The mechanism that prevented the establishment of woody vegetation along the Platte River was the scouring and movement of sand in the riverbed during high flow periods (Eschner et al. 1981; Currier et al. 1985). Before high flows were lost due to water storage projects, the spring flows scoured away seedlings that had become established (Eschner et al. 1981; Hadley and Eschner 1981). Today, the mechanism that controlled the establishment of woody vegetation is no longer present. The numerous reservoirs have brought about a decrease in flood flows (Eschner et al. 1981; Hadley and Eschner 1981; Currier 1982; Krapu et al. 1982). The reduction in flood flows has allowed for the establishment of woody vegetation on sandbars by reducing the effects of scouring (Frith 1974; Eschner et al. 1981; U.S. Fish and Wildlife Service 1981; Krapu et al. 1982).

In recent years, the cumulative effects of agricultural drainage, reduced flows, and pumping of groundwater for center pivot irrigation has acted to lower groundwater levels during the summer months (Krapu et al. 1982). This has lead to conversion of native wet meadows to cropland and has resulted in reduction of the habitat where sandhill cranes feed on invertebrates (Reinecke and Krapu 1986). A survey undertaken a decade ago indicated that 75% of the native wet meadows had been converted to cropland between Overton and Grand Island (U.S. Fish and Wildlife Service 1981).

SANDHILL CRANES. Changes in river morphology and discharge, as well as encroachment of woody vegetation, brought about by water development have altered habitat for migratory birds (U.S. Fish and Wildlife Service 1981). Foremost among the concerns has been the impact of habitat alterations on sandhill cranes. In recent years, considerable attention has been focused on the concentrations of sandhill cranes that congregate along the Big Bend Reach of the Platte River during their annual spring migration from March to early April. During this time, approximately 400,000 (Solberg 1989) sandhill cranes use this area while en route to their breeding grounds in Canada, Alaska, and eastern Siberia (U.S. Fish and Wildlife Service 1981). Their winter distribution extends across western Texas and eastern New Mexico (Lewis 1977; Walkinshaw 1981). Most of these birds are of the Canadian (*G. c. rowani*) and lesser (*G. c. canadensis*) races (Aldrich 1979; Walkinshaw 1981).

The Big Bend Reach of the Platte River has been described as the only major stopover area for sandhill cranes migrating from the wintering areas to the nesting grounds (Buller and Boecker 1965; Frith 1974; Lewis 1974). Frith (1974) compared the North American range of sandhill cranes as being analogous to the shape of an hourglass with the top being the nesting grounds, the bottom being the wintering areas, and the restricted portion at the center being the Big Bend Reach of the Platte River. The Platte River portion of their range is believed to be the weak link in their total habitat requirements because the population is extremely vulnerable to habitat loss within this area (Frith 1974). In fact, habitat loss has caused the abandonment of over two-thirds of the original habitat used by sandhill cranes in the Platte River and North Platte River valleys (U.S. Fish and Wildlife Service 1981). Presently, 80% of the midcontinent population of sandhill cranes is confined to only 44 km of the Platte River and North Platte River each spring (U.S. Fish and Wildlife Service 1981).

Proposed water development projects are raising concerns over additional habitat loss and the future of the sandhill crane. The impact that proposed water development may have on discharge needed to maintain sandhill crane habitat is being assessed by the U.S. Bureau of Reclamation and the U.S. Fish and Wildlife Service. Both agencies have expressed interest in the use of Habitat Suitability Index (HSI) models to assess habitat needs and to interpret the significance of existing habitat conditions along the Big Bend Reach of the Platte River.

<u>HABITAT SUITABILITY INDEX MODELS</u>. Habitat Suitability Index (HSI) models are designed for a wide variety of land use planning applications where habitat information is important in the process of decision making. The models

can be used to improve understanding and to predict habitat relation of species, but they cannot be regarded as statements of proven cause and effect relations (Armbruster 1987). Most HSI models have been developed by incorporating both biological and habitat information from published literature along with information from experts in the field. Habitat needs of a species are generally subdivided into manageable subcomponents and a set of measurable variables along with species habitat relationships are identified that define habitat requirements of a species. Habitat relations are constructed to compare measured variables with optimum conditions for a species. Comparison of measured conditions with optimum conditions results in habitat suitability index (HSI) values between 0.0 (unsuitable habitat) and 1.0 (optimum habitat) for each habitat subcomponent (Armbruster and Farmer 1982; Armbruster 1987). HSI models provide a way to quantitatively describe habitat suitability for species and to determine the impact of land management decisions on species. However, the ability of HSI models to withstand scientific and legal scrutiny is dependent on testing and verification of performance in the field.

A lack of information on habitat requirements of sandhill cranes prompted the development of a draft HSI model by Armbruster and Farmer (1982). This model was defined as applicable to a 5.6-km band on both sides of the Platte River between Overton and Chapman, Nebraska. The model was developed by experts who participated in the 1981 Crane Workshop (Armbruster and Farmer 1982). Participants identified variables that were considered important in providing optimum habitat for sandhill cranes along the Platte River. The major components were: (1) grain food, (2) invertebrate food, and (3) roosting requirements. Of these three components, roosting requirements were considered the key dimension of the model.

It is generally recognized that the distribution of roost sites along the Platte River is a function of channel habitat features (Frith 1974; Lewis 1974; U.S. Fish and Wildlife Service 1981; Krapu et al. 1984). The features that characterize roost sites include relatively isolated areas free from human disturbance and wide channels with sparsely vegetated shorelines (Frith 1974; Lewis 1974; U.S. Fish and Wildlife Service 1981; Krapu et al. 1982, 1984), as well as relatively shallow water (Frith 1974; Lewis 1974; Iverson et al. 1987). These requirements were incorporated in the roosting component of the model in the form of three variables: (1) mean depth of water, (2) area of unobstructed view from the edge of a flock, and (3) presence or absence of disturbance factors within a defined distance from the channel.

Seminar participants felt that water depth was an important variable in determining roost site selection. The optimum water depth for roosting was believed to range from 10.2 to 20.3 cm, whereas water deeper than 35.6 cm was considered unsuitable for roosting.

Since sandhill cranes are believed to rely on the eyesight of flock members to detect potential threats from predators, some minimum area of unobstructed view while on roosting sites is probably required. The model stated that a minimum of 25 m of unobstructed view in all directions is required, or a minimum unobstructed channel width of 50 m. Optimum conditions were believed to occur when 75 m or more of unobstructed view occurred, or a minimum unobstructed channel width of 150 m.

Human disturbance was also identified as important in the selection of roosting sites. The disturbance factors included bridges, powerlines, paved highways, gravel roads, railroads, urban dwellings, and recreational areas. The model gave each disturbance feature a specific zone of influence that affects the use of roost sites. However, the presence of a visual barrier between the disturbance feature and the river channel may act to reduce or eliminate the disturbance potential.

LITERATURE REVIEW

The sandhill crane is considered as one of the oldest living contemporary avian species, with fossil remains found from the Pliocene in Nebraska (Walkinshaw 1949). Currently, six sandhill crane subspecies are recognized (Lewis 1977). The Florida sandhill crane (*Grus canadensis pratensis*), Mississippi sandhill crane (*G. c. pulla*), and Cuban sandhill crane (*G. c. nesiotes*) are sedentary (Lewis 1977; McMillen 1988) and have relatively small populations along with a restricted range (McMillen 1988). In contrast, the greater sandhill crane (*G. c. tabida*), lesser sandhill crane (*G. c. canadensis*), and the Canadian sandhill crane (*G. c. rowani*) are migratory and possess relatively large, stable populations with extended ranges (Lewis 1974; Walkinshaw 1981). The two most abundant subspecies are the lesser and Canadian sandhill cranes, with the lesser sandhill crane being by far the most abundant of the two (Walkinshaw 1981). Lesser sandhill cranes generally breed on the tundra in northwestern Canada, northeastern Siberia, and on the Kuskokuim Delta in Alaska (Lewis 1977; Walkinshaw 1981; Mickelson 1985). Canadian sandhill cranes breed in boreal portions of the Canadian Shield on prairies and marshes (Walkinshaw 1965). Breeding pairs of both lesser and Canadian sandhill cranes select shallow water marshes or bogs for nesting (Lewis 1977). Nests are usually established in shallow water and consist of piles of emergent aquatic vegetation, grasses, sphagnum and mud (Walkinshaw 1949, 1965; Lewis 1977). Nesting is usually underway by the last week in May. Clutches usually contain from one to two eggs. The incubation period is 28 to 31 days with the eggs hatching in an asynchronous fashion. After colts hatch, the crane family moves to meadows where the colts feed almost exclusively on animal food (Lewis 1977).

Population estimates of breeding sandhill cranes are difficult to obtain because breeding pairs are scattered. Estimates are obtained when sandhill cranes come together and stage during their fall migration. Mickelson (1985) reported that nearly 200,000 lesser sandhill cranes from the Central Flyway stage in Alaska for their fall migration from August through October. With the advent of winter, the sandhill cranes leave the north and begin migrating to their wintering grounds in the southwestern United States (Buller 1967; Lewis 1977). Lesser sandhill cranes winter on the plains of eastern New Mexico and western Texas (Lewis 1977; Walkinshaw 1981). The Canadian sandhill cranes generally winter on the Coastal Plain of southeastern Texas (Walkinshaw 1965a) and Mexico, but have also been known to winter in western Texas and eastern New Mexico as well (Buller 1967). Iverson et al. (1985) reported a seemingly high population estimate of 400,000 lesser sandhill cranes wintering in these areas.

Scattered distributions of sandhill cranes on their wintering grounds in New Mexico, Texas, and northern Mexico have made it difficult to obtain an accurate census of sandhill crane numbers (Munro and Lewis 1976; Benning and Johnson 1985). However, virtually all of the sandhill cranes that winter in the aforementioned areas stop along the Platte and North Platte rivers in south central Nebraska during their spring migration to the breeding grounds (Frith 1974; Lewis 1974; U.S. Fish and Wildlife Service 1981; Krapu et al. 1982). Lewis (1977) reported that the entire continental population of Canadian sandhill cranes and all but 20,000 of the Pacific Flyway population of lesser sandhill cranes stage along the Platte and North Platte rivers each spring. The concentration of these sandhill cranes into a confined geographic area during late March, makes it possible to obtain an accurate census of crane populations during this period (Munro and Lewis 1976; Benning and Johnson 1985).

In 1957, the U.S. Fish and Wildlife Service began an annual census of sandhill cranes along the Platte River in south central Nebraska. The census technique described by Wheeler and Lewis (1972) was designed to show population trends and not to estimate the number of sandhill cranes (Munro and Lewis 1976). During the period from 1971-1972, the census technique was altered so estimates of the number of sandhill cranes seen on river roosts were obtained (Frith 1974). In July 1981, a management plan was developed by the Central Flyway Waterfowl Council for the management of the mid-continental population of sandhill cranes in a cooperative effort between state and federal agencies. The primary goal of the plan was to maintain the population of sandhill cranes between 480,000 and 590,000 individuals (Benning and Johnson 1985). This presented the need for obtaining reliable estimates of sandhill crane populations and for improvement of existing survey techniques. Several authors describe improvements made in survey design since 1978 through the use of [illegible] oblique photographic techniques (Ferguson et al. 1979; Benning and Johnson 1985).

The accuracy of sandhill crane censuses along the Platte and North Platte rivers from 1957-1977 is questionable. Frith (1974) emphasized that the results of the censuses were dependent upon weather conditions, censusing techniques, and human judgement as to whether sandhill cranes had reached their peak numbers at the time of the survey. Nevertheless, Buller (1979) reported that the maximum size of the sandhill crane population along the Platte and North Platte rivers ranged from 80,315 to 225,945 in 1959 and 1978, respectively.

In contrast to ocular estimates made from 1957 to 1978, the U.S. Fish and Wildlife Service (1981) used direct photographic surveys involving oblique techniques to estimate the maximum size of the sandhill crane population in 1979 and 1980, which was 306,000 and 541,000 birds, respectively. Tests performed by the U.S. Fish and Wildlife Service in 1978 and 1979 indicated that ocular techniques underestimated the sandhill crane population by 30% (U.S. Fish and Wildlife Service 1981). Despite the lack of documentation on sandhill crane populations along the Platte and North Platte rivers since 1980, it is generally accepted that the population has been relatively stable for the past few years and is at approximately 400,000 birds (Solberg 1989).

Various factors have contributed to the Platte and North Platte River valleys becoming the primary spring staging area for 80% of the midcontinent population of sandhill cranes. Krapu et al. (1984) described the establishment of fenced fields and trespass laws that restrict access to private lands, thus preventing human harassment of sandhill cranes. Another source of disturbance that was removed was spring hunting through the establishment and enforcement of the Migratory Bird Treaty Act of 1918. Krapu et al. (1984) pointed out that loss of habitat elsewhere has caused the increased use of staging areas along the Platte River valley. But, perhaps the greatest factor contributing to the abundant sandhill crane population in this area is the high quality roosting and feeding habitat available (Krapu et al. 1984).

FEEDING ECOLOGY. A number of investigators have studied the feeding ecology of sandhill cranes during spring migration in the Platte River valley (Lewis 1979; Reinecke and Krapu 1979, 1986; U.S. Fish and Wildlife Service

1981; Iverson et al. 1982; Krapu et al. 1984; Tacha et al. 1987). Much of the current knowledge was obtained from a 3-year investigation by the U.S. Fish and Wildlife Service known as the Platte River Ecology Study (U.S. Fish and Wildlife Service 1981).

Krapu et al. (1984) stated that 97% of the habitat used by sandhill cranes during 1978 and 1979 was cropland, native grassland, and hayland. Bird use of cropland was 44% in 1978 and 61% in 1979. In 1978 all cropland use was cornfields, primarily grazed corn stubble (61%). In 1978, 99% of all cropland use was cornfields, 52% was grazed stubble and the remaining 1% was winter wheat and milo. The use of native grasslands remained constant during both years (28%), while use of tame haylands dropped from 27% to 9% between 1978 and 1979. Iverson et al. (1987) reported similar habitat use patterns for the same area with corn stubble receiving the greatest use (41%) followed by pasture (28%) and alfalfa (20%). Other investigators have found slightly different habitat use patterns. Lovvorn and Kirkpatrick (1982) reported that field use by greater sandhill cranes in Indiana consisted predominately of corn (58%), soybeans (21%), and fallow pasture (18%). Winter wheat comprised only 3% of total use, but was preferred as much as corn. In contrast, Hoffman (1976) stated that greater sandhill cranes in Michigan "showed the strongest average preference for wheat" from among the field types available.

The primary food source of sandhill cranes in the Platte River valley was waste corn, which constituted 98% of the bulk of their diet (Iverson et al. 1982). Reinecke and Krapu (1979) estimated that waste corn comprised 96% of dry matter intake of sandhill cranes. Lewis (1979) found that corn constituted 89% of the volume of gullet contents of sandhill cranes sampled along the Platte River. Walker and Schemnitz (1985) describe similar findings to those of Lewis

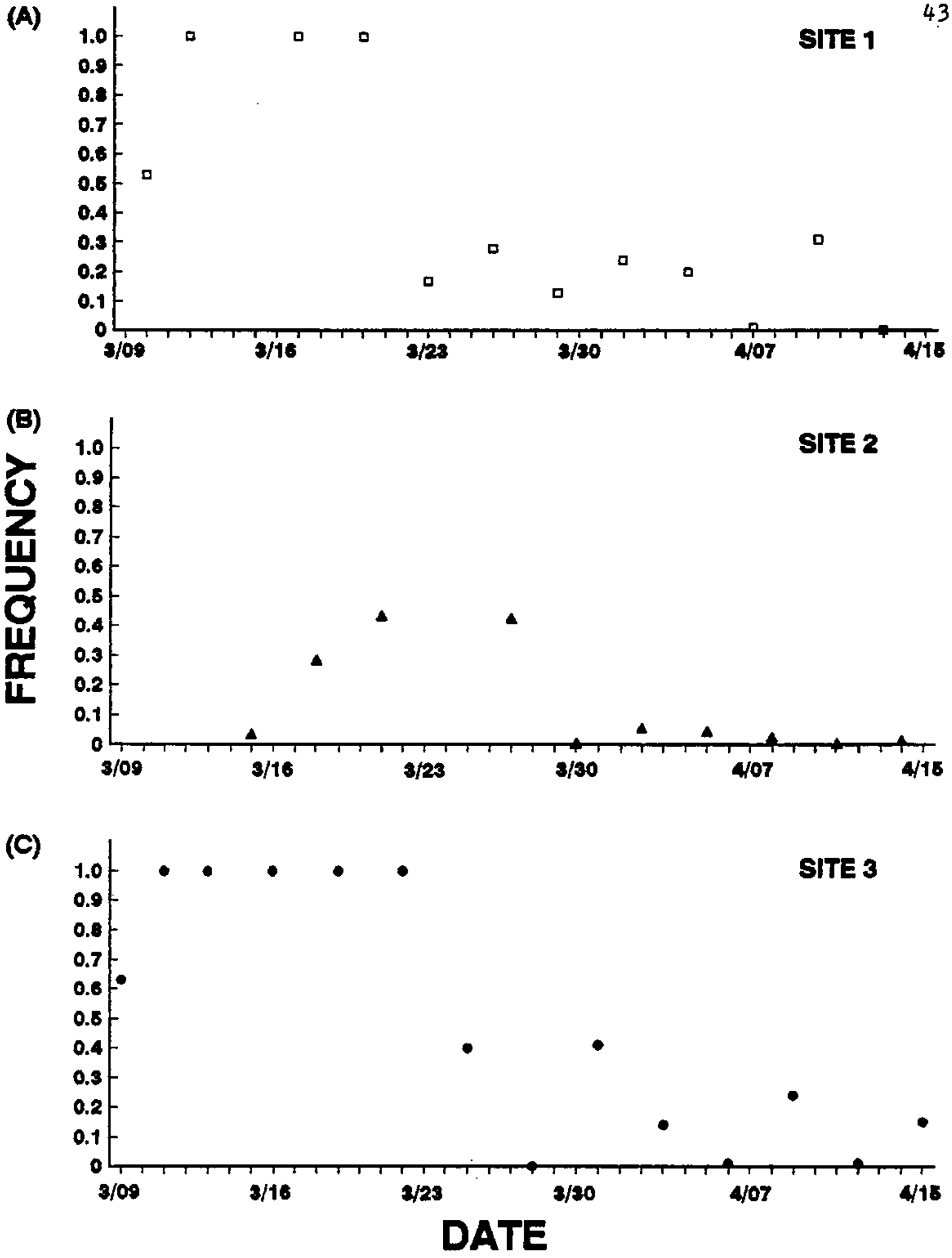


Fig. 5. Seasonal Trend in the Proportion of Sandhill Cranes Departing the Roost Before Sunrise at (A) Site 1, (B) Site 2, and (C) Site 3 during the Spring Roosting Season Along the Platte River, Nebraska, 1990.

The time when 91-100% of the flock departed was best exemplified by IDT. DATE was significant in accounting for the time when 91-100% of the flock had left the roost, but had a lower correlation than IDT. The other independent variables, FOG/PREC and TEMP were not correlated with the time of 91-100% flock departure.

FLOCK FORMATION. There were no differences in arrival times among sites (Table 5), however, initial arrival time varied temporally ($\underline{P} < 0.0001$) (Table 6). Sandhill cranes were arriving at the roost earlier from 4-14 April than the period from 9 March-3 April (Fig. 6). Initial arrival time averaged 60 and 49.6 minutes earlier from 4-14 April than the respective periods from 9-21 March and 22 March-3 April (Table 6).

Not [illegible]

Similarly, the proportion of the flock arriving at the roost before sunset also varied temporally ($\underline{P} < 0.0001$) (Table 6). The percentage of sandhill cranes arriving at the roost was significantly higher from 4-14 April than 9 March-3 April. The percentage of the flock arriving before sunset averaged 7% from 9 March-3 April, then increased sharply from 4-14 April, averaging 57% toward the end of the staging season (Fig. 7).

Sandhill cranes were arriving at the roost at a far greater rate during the formation of the first half of the flock than the later half (Fig. 8). This trend was apparent during the entire staging season. Differences between the rate of arrival from the time when the flock was initially formed to half formed were significant ($\underline{P} < 0.0004$), as was the difference between arrival rates from the time the flock was half formed to fully formed ($\underline{P} < 0.0001$) (Table 7). The rate of arrival during 9 March-3 April was comparatively higher than the period from 4-14 April ($\underline{P} < 0.05$) (Fig. 8). Between 9-21 March and 22 March-3 April, the first half of the flock formed at a rate which averaged 13.3 and 7.9

Table 5. Mean Time of Initial Arrival and Arrival when 11-20, 41-50, and 91-100% of the Flock has Formed at Three Sites along the Platte River, Nebraska from March to mid-April 1990.

		Time in minutes before (+) and after (-) sunset							
		Initial arrival		11-20% arrival		41-50% arrival		91-100% arrival	
Site	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1	13	- 2.7	8.3	- 4.6	8.2	-10.4	7.0	-25.0	5.8
2	10	+12.0	10.2	+ 5.0	6.5	- 3.0	5.7	-24.5	2.8
3	13	- 1.5	10.9	- 6.9	9.6	-18.1	8.2	-38.8	3.9

Table 6. Comparisons of Mean Values Among Three Different Time Periods for Time of Initial Arrival and Percent of the Flock Arriving at the Roost Prior to Sunset.

Date	n	Initial arrival time[a]		Percent of flock arriving at roost before sunset	
		$\overline{x}$	SE	$\overline{x}$	SE
9 March - 21 March	13	-20.0	5.4	0.06	0.04
22 March - 3 April	12	- 9.6	4.5	0.08	0.06
4 April - 14 April	11	+40.0	9.2	0.57	0.09

[a] In minutes before (+) and after (-) sunset.

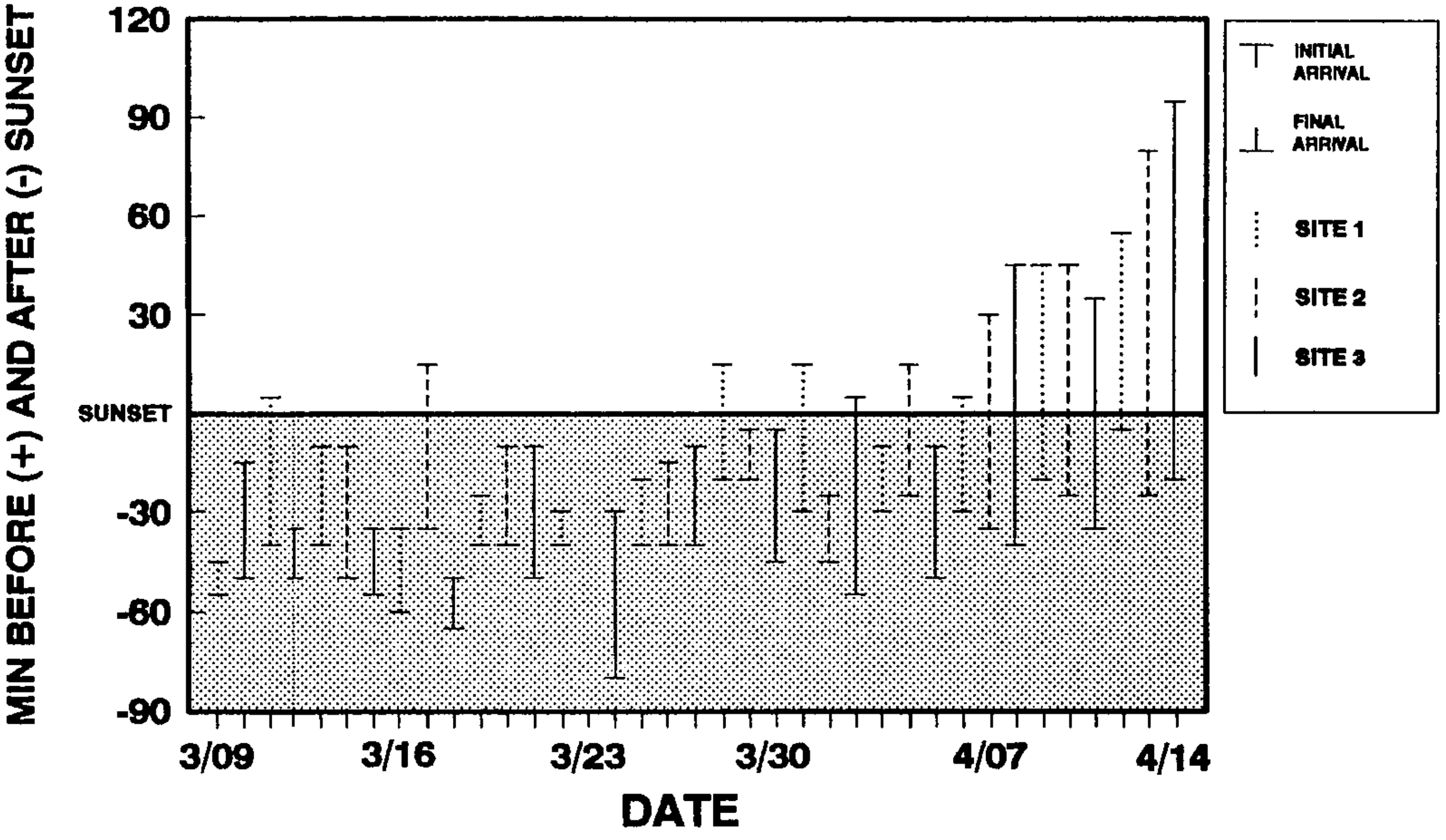


Fig. 6. Seasonal Variation in the Timing and Duration of Arrival of Sandhill Cranes at the Roost Among Different Sites during Their Spring Staging Halt Along the Platte River, Nebraska, 1990.

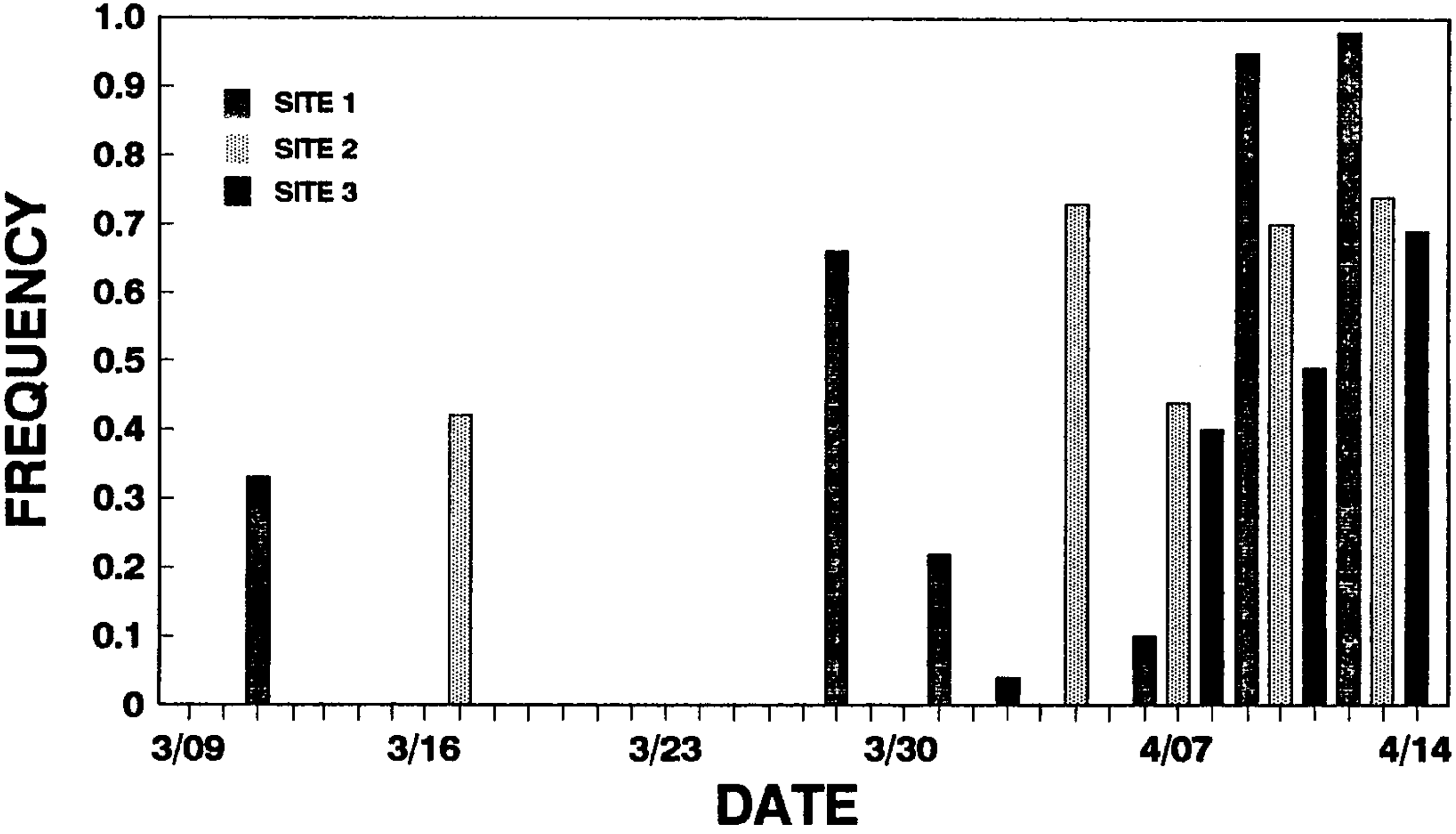


Fig. 7. The Influence of the Time of the Staging Season (Date) on the Proportion of Sandhill Cranes Arriving at the Roost Prior to Sunset at Different Sites during Spring Stopover Along the Platte River, Nebraska, 1990.

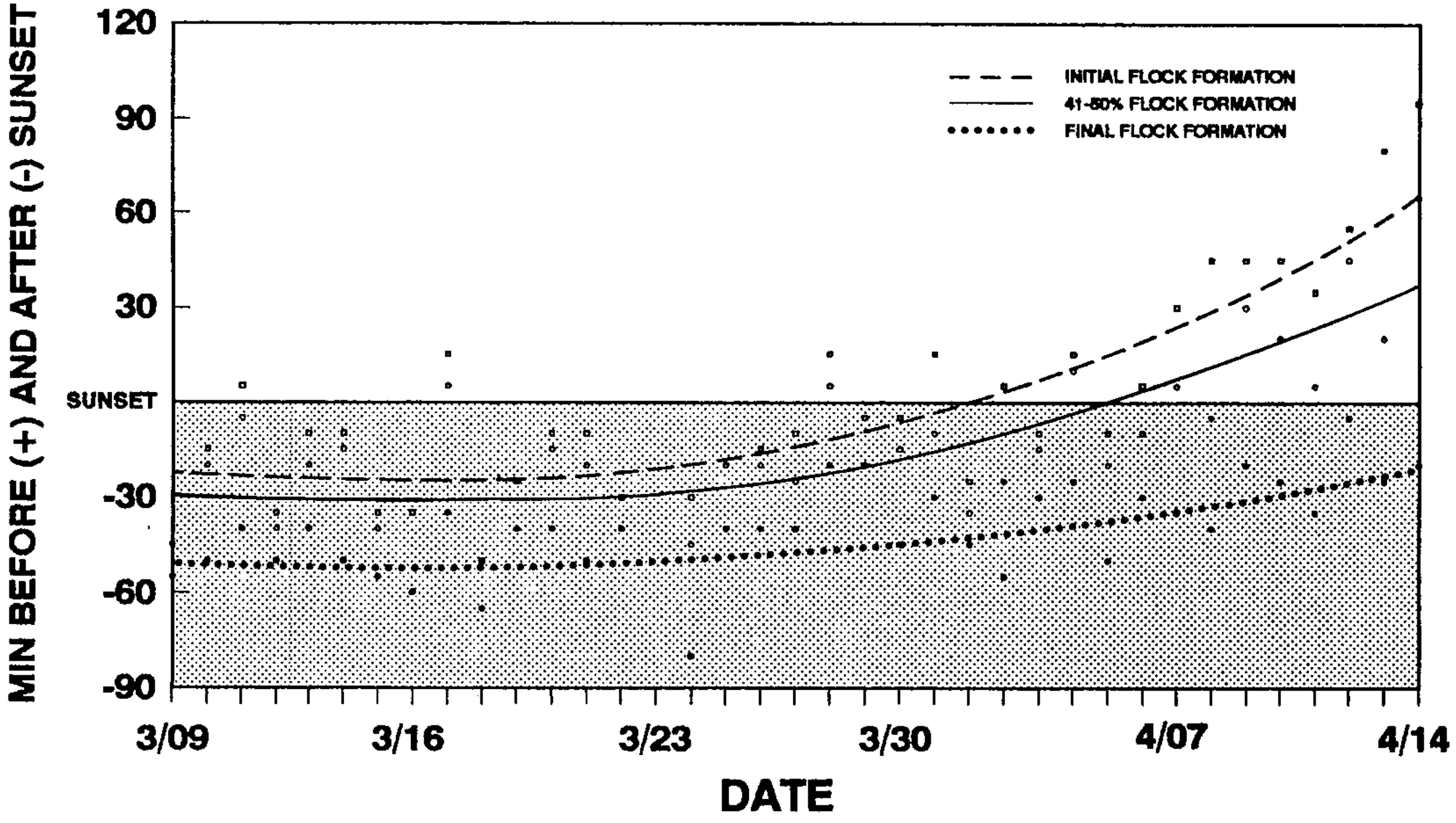


Fig. 8. Seasonal Trend in the Time of Initial, Mid, and Final Flock Formation and the Relative Arrival Rates (between Lines) of Sandhill Cranes during Their Spring Staging Halt Along the Platte River, Nebraska, 1990. Open Squares Denote Initial Arrival Times; Open Circles are Times of 41-50% Flock Formation. Solid Circles Depict Final Arrival Times.

Table 7. Comparative Mean Rates of Arrival Among Three Different Time Periods, from the Time when the Flock was Initially Formed to Approximately Half Formed, Time when the Flock was Half Formed to Fully Formed, and Total Length of Time from Initial to Final Flock Formation.

		Time in minutes					
		Length of time between initial arrival and 41-50% flock formation		Length of time between 41-50% flock formation and final flock formation		Total length of arrival	
Date	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
9 March - 21 March	13	5.0	1.1	23.5	2.8	28.4	3.6
22 March - 3 April	12	10.4	2.8	20.4	2.3	30.8	4.4
4 April - 14 April	11	25.0	5.2	43.2	5.0	68.2	7.8

minutes greater, respectively, than the period from 4-14 April. During the later half of flock formation, differences were even greater. The rate of formation of the remaining half of the flock averaged 15.5 and 18.6 minutes less from 4-14 April than the respective periods from 9-21 March and 22 March-3 April. Likewise, the total length of time from initial to final flock formation was characterized by a significant increase during 4-14 April ($\underline{P} < 0.05$) (Table 7). The total length of flock formation averaged 39.8 and 37.4 minutes longer from 4-14 April than 9-21 March and 22 March-15 April, respectively.

Abiotic Factors. Time of initial arrival was highly correlated with date and various climatic variables (Appendix C). Variability in time of initial arrival was best accounted for by DATE, DATE^2, CLOUDCOV, and TEMP (Table 8).

Time when 11-20% of the flock had formed was highly correlated with IAT. The variables DATE, DATE^2, CLOUDCOV, and TEMP in combination, also accounted for a great deal of variability in time at which 11-20% of the flock had arrived at the roost and were all positively related to arrival time (Table 8).

The time when 41-50% of the flock had formed was best accounted for by IAT singly. The polynomial regression of DATE, DATE^2, and CLOUDCOV was also an important determinant of the time when 41-50% of the flock had arrived at the roost. The inclusion of TEMP as an independent variable in the regression did little to improve the overall model.

Variability in time when 91-100% of the flock was formed was best explained by IAT. The variable DATE was significant in accounting for the time when 91-100% of the flock had arrived at the roost, but was not correlated as closely with arrival time as was IAT. The other independent variables DATE^2,

Table 8. Regression Equations Accounting for Variability in Arrival Time (Y) for IAT, T20, T50, and T100. Arrival Time is Described as Time of Initial Arrival (IAT)[a], Time when 11-20 (T20), 41-50 (T50), and 91-100% (T100) of the Flock had Formed. Independent Variables are Day of the Year (DATE), Day of the Year Squared $(\text{DATE})^2$, Percent Cloud Cover (CLOUDCOV)[b], Air Temperature (TEMP)[c], and Initial Arrival Time (IAT).

Dependent variable	$\underline{R}^2$	Adjusted $\underline{R}^2$	Equation
(IAT)	0.86	0.84	$Y = -37.44 + 2.54(\text{DATE}) + 0.10(\text{DATE})^2 + 4.26(\text{CLOUDCOV}) + 1.55(\text{TEMP})$
(T20)	0.94	0.94	$Y = -4.16 + 0.84(\text{IAT})$
	0.79	0.76	$Y = -36.78 + 2.09(\text{DATE}) + 0.08(\text{DATE})^2 + 4.18(\text{CLOUDCOV}) + 1.31(\text{TEMP})$
(T50)	0.87	0.87	$Y = -12.36 + 0.69(\text{IAT})$
	0.73	0.70	$Y = -40.70 + 1.68(\text{DATE}) + 0.72(\text{DATE})^2 + 3.80(\text{CLOUDCOV}) + 1.05(\text{TEMP})$
	0.69	0.67	$Y = -33.53 + 1.58(\text{DATE}) + 0.93(\text{DATE})^2 + 3.54(\text{CLOUDCOV})$
(T100)	0.56	0.55	$Y = -30.54 + 0.37(\text{IAT})$
	0.42	0.40	$Y = -118.62 + 1.03(\text{DATE})$

[a] Time in minutes before and after sunset.
[b] Coded for 1 = clear, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, 5 = >75% (overcast).
[c] In °C.

CLOUDCOV, and TEMP were not correlated with the time of 91-100% flock formation.

NOCTURNAL ACTIVITY. During the evening roosting period, resting was the dominant activity of sandhill cranes. Standing was the second most important activity, preening the third; flying, walking, alert, courtship, and agonistic activities accounted for the balance (Fig. 9).

Time of night had a strong influence on the overall activity patterns of cranes. The early night (final arrival-2100 hrs) and early morning (0505-initial departure) periods were the times of greatest overall activity and movement (Fig. 9). Trend analysis indicated a significant bimodal trend in standing ($\underline{P} < 0.0001$), walking ($\underline{P} < 0.005$), and preening ($\underline{P} < 0.002$) activities throughout the evening. Sandhill cranes spent more time standing during periods 1 and 4 than 2 and 3. Walking activity was greater during period 4 than either periods 2 or 3, but was not significantly different than period 1. Time spent in preening activity was greater during period 1 than period 2 and 3, but did not differ from period 4. Correspondingly, overall activity of sandhill cranes declined during periods 2 and 3 (Fig. 9). Sandhill cranes spent less time in locomotory behavior and more time resting during these periods. Resting activity was significantly higher during periods 2 and 3 than period 1, but only period 3 was significantly higher than period 4. Time spent resting did not differ between periods 2 and 4. Other activities such as flying, alert, agonistic, and courtship were observed infrequently and at similar rates. No differences were found in the time spent in each of these activities among periods of the night.

No seasonal effect of the overall activity patterns of sandhill cranes was detectable (Fig. 10). General activity patterns remained essentially unchanged from 19 March through 9 April. However, during periods 1 and 2 on 3 April

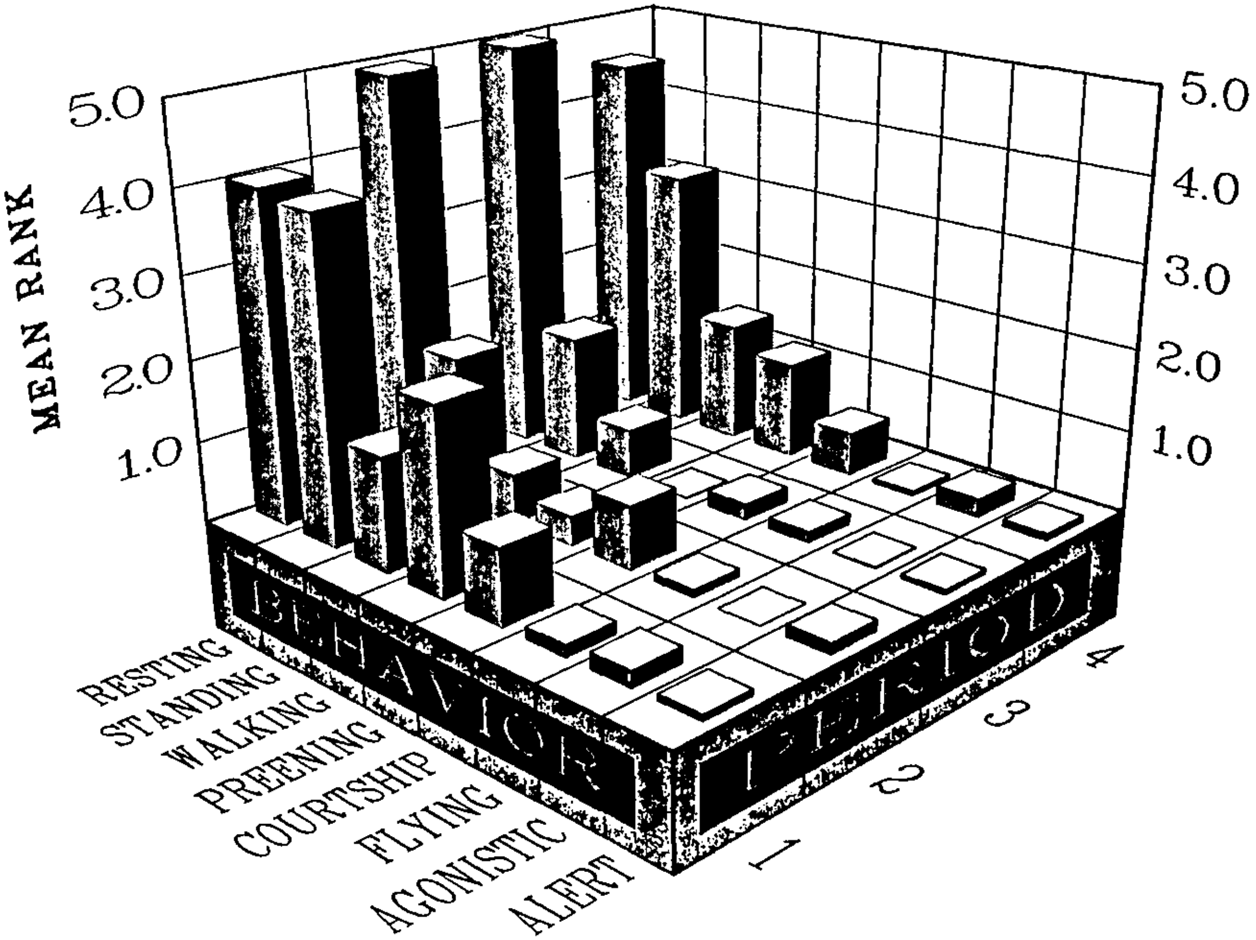


Fig. 9. Relative Frequency (Mean Rank) of Nocturnal Behavioral Activities of 5 Sandhill Crane Flocks during 4 Periods of the Night, 19 March-9 April 1990, Along the Platte River, Nebraska. Period 1 was from Time of Final Flock Formation-2100 hr (CST), Period 2 from 2105-0100 hr, Period 3 from 0105-0500 hr, and Period 4 was from 0505 hr-Time of Initial Departure. Ranks Varied from 5 (Dominant Activity) to Zero (Behavior Absent).

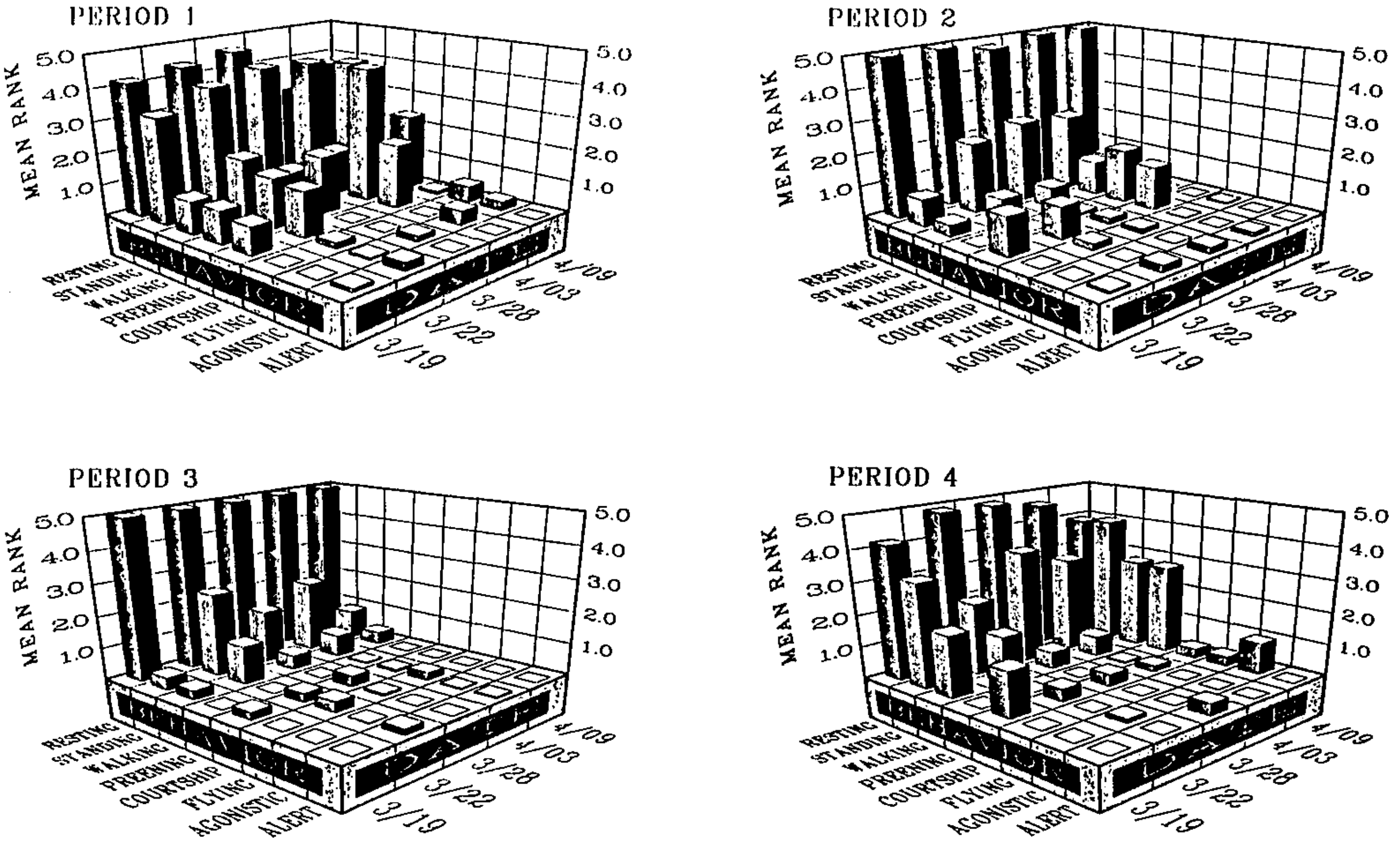


Fig. 10. Comparison of Seasonal Variation in the Relative Frequency (Mean Rank) of Nocturnal Behavioral Activities of Sandhill Cranes among Different Periods of the Night Along the Platte River, Nebraska During Spring Stopover, 1990. Period 1 was from Time of Final Flock Formation-2100 hr (CST), Period 2 from 2105-0100 hr, Period 3 from 0105-0500 hr, and Period 4 was from 0505 hr-Time of Initial Departure. Ranks Varied from 5 (Dominant Activity) to Zero (Behavior Absent).

there was a disproportionately high peak in preening, walking, and courtship activities (Fig. 10).

Weather had little effect on the general activity patterns of sandhill cranes (Table 9). Correlations between climatic variables and behavioral activities were generally low and nonsignificant. An exception occurred with flying and preening which were positively correlated with wind speed and temperature, respectively.

DISCUSSION

This study demonstrated a trend in the timing of roosting activities during the staging season. Departure times were earliest, arrival times latest, and the rate of departure and arrival were highest at the beginning of the staging season (9-21 March). However, during mid (22 March-3 April) to late (4-15 April) staging season there was a substantial change in the timing of roost activity, as departure times were later, arrival times earlier, and departure and arrival rates were considerably lower.

FLOCK DEPARTURE. Departure rates differed among sites. The duration of departure at Sites 1 and 3 was relatively short from 9-25 March, but increased thereafter, whereas the duration of departure at Site 2 remained relatively constant throughout the staging season (Fig. 2). Moreover, on average, Site 2 had a significantly longer departure time than either Site 1 or 3. Why cranes remained on the roost longer at Site 2 than either of the other sites is unknown, but cranes arrived at Site 2 a full week later than Site 1 or 3.

Initial departure times varied temporally. Sandhill cranes were leaving the roost earlier at the beginning of the staging season (9-21 March). During

Table 9. Spearman Rank Correlation Coefficients of Selected Weather Variables with Behavioral Activities of Roosting Sandhill Cranes During Their Spring Staging Halt along the Platte River, Nebraska, 1990.

Variable	Flying	Standing	Walking	Preening	Alert	Resting	Courtship	Agonistic
Fog/Precipitation	0.15	0.29	0.25	0.34	-0.16	-0.24	-0.40	0.37
Wind speed[a]	0.51*	-0.25	0.05	-0.28	0.15	0.25	-0.09	0.13
Temperature[b]	0.03	0.18	-0.09	0.51*	0.06	-0.15	-0.09	0.06

*Indicates a significant correlation at $P \leq 0.05$.

[a] Coded for 1 = calm, 2 = 1-16 km/hr, 3 = 17-32 km/hr, 4 = 33-48 km/hr, 5 = > 48 km/hr.

[b] In °C.

this time, they occasionally left the roost as early as 45 minutes before sunrise. In contrast, Frith (1974) observed sandhill cranes leaving roosts along the Platte River as early as 2 hours before sunrise. The time of initial departure during the end of the staging season (4-15 April) averaged 22.5 minutes later than the period from 9-21 March. Iverson et al. (1987) and Lewis (1974) reported similar initial departure times for sandhill cranes along the North Platte River in Nebraska and in Kansas and Oklahoma, respectively. Stephen (1967) found that in Saskatchewan, sandhill cranes began to leave the roost approximately 23 minutes before sunrise.

Percent of the flock leaving the roost before sunrise varied temporally. The percentage of sandhill cranes departing from the roost averaged 74% during the beginning of the staging season, then declined sharply to 17% from mid- to late-season. Similarly, Lewis (1974) reported that an estimated 18% of the sandhill cranes had departed the roosts by sunrise in Kansas and Oklahoma. Stephen (1967) and Lewis (1978) stated that an average of 25% of the sandhill cranes left their roosts by sunrise in Saskatchewan and Nebraska, respectively.

FLOCK FORMATION. Arrival times did not differ among sites, but did vary temporally. Sandhill cranes arrived at roosts earlier from 4-14 April than the period from 9 March-3 April. The mean time of initial arrival during the end of the staging season was 40 minutes before sunset. In describing roosting behavior of sandhill cranes in Kansas and Oklahoma, Lewis (1974) noted that birds occasionally arrived at the roost as early as 2 to 3 hr before sunset, but more commonly arrived at the roost prior to 100 minutes before sunset. Other evidence of early arrival times included observations made by Frith (1974) of roosting sandhill cranes along the Platte River in Nebraska. He maintained that most of the cranes arrived at the roosts between 1 hr before sunset to about 0.5 hr after sunset. In a recent study, Iverson et al. (1987) reported a later arrival time, which averaged 6.5 minutes after sunset for radio equipped cranes on river roosts along the North Platte River in Nebraska.

Percent of the flock arriving at the roost before sunset also varied during the staging season. The percentage of sandhill cranes arriving at the roost averaged 7% from 9 March-3 April, then increased sharply from 4-14 April, averaging 57% toward the end of the staging season. Similarly, Lewis (1974) observed that in Kansas and Oklahoma, 56% of the sandhill cranes had arrived at the roost prior to sunset. In a study of roosting behavior of sandhill cranes along the Platte River in Nebraska, Lewis (1978) reported that 64% of the birds had arrived at the roost by sunset.

[illegible]

On several occasions large numbers of sandhill cranes were observed roosting at Site 2 throughout the day into the evening. During this time, sandhill cranes were involved in such activities as loafing, preening, drinking, and flying back and forth from the river to feeding areas. Similar patterns of diurnal roost activity were reported by Lewis (1976) for sandhill cranes in Kansas and Oklahoma. Diurnal roost activity may be attributable to the characteristically mild weather conditions that occur during such activity (Lewis 1976). But, because this behavior was not observed at any of the other sites during equally favorable weather conditions, the implication is that this behavior is exclusively site specific. Perhaps these sandhill cranes that roosted early were migrating birds passing through the area (Lewis 1976) or perhaps these birds were non-traditional migrants to the area, which may explain why these birds arrived at this roost a week later than either Site 1 or 3.

ABIOTIC FACTORS. Date of the staging season appeared to be the primary determinant of time of initial departure and arrival at the roost sites.

Increasing time at the roost sites coincided with increased body fat deposition during the time spent within the Platte River Valley. Krapu et al. (1985) determined that the greatest rate of fat accumulation in female sandhill cranes occurred from 5-24 March. During this time, fat content nearly doubled from 6.7% during 5-14 March to 12.2% during 15-24 March. In addition, data provided by T. E. Fannin (U.S. Fish and Wildlife Service, Grand Island, Nebraska, unpublished data 1989-90) indicated high levels of subcutaneous fat in sandhill cranes early on in the staging season and a substantial increase in the proportion of cranes with excessive amounts of fat from mid- to late-season (Appendix E). It seems likely that the timing of roosting activity was influenced by lipid accumulation. Below some threshold of body fat deposition sandhill cranes spend more time foraging in order to satisfy energy requirements. However, when lipid accumulation reaches a threshold level they spend more time on the roosts.

Fog or precipitation was also found to influence initial departure time. Sandhill cranes remained on roosts longer during mornings with fog and precipitation; probably because fog and precipitation limit visibility and makes flight more hazardous. Lewis (1978) observed that rain or fog, as well as cloud cover and strong winds (> 48 km/hr), delayed departure. In contrast, Frith (1974) reported that high wind velocities (> 32 km/hr) promoted earlier departures. My study did not indicate wind speed or cloud cover to be determinants of initial departure time. However, cloud cover was found to influence initial arrival time. Sandhill cranes arrived earlier at the roost during periods of increased cloud cover, perhaps because cloud cover caused a decreased light level.

Air temperature also explained some variability in initial departure and arrival time. During periods of cold weather, birds left roosts and arrived at roosts later. This implies a thermodynamic advantage to feeding later during the morning and during dusk when temperatures are colder. A similar relation has been described for black ducks (*Anas rubripes*). Albright et al. (1983) observed that during cold temperatures it was more advantageous for black ducks to conserve energy resting than to expend energy foraging.

NOCTURNAL ACTIVITY. This study indicated that activity patterns of roosting sandhill cranes vary through the night. Cranes were most active upon arrival to 2100 hr (Central Standard Time). From $\overset{9:00}{2105}$ to $\overset{5:00}{0500}$ hr they were often inactive (i.e. resting), but activity intensified again near dawn (from 0505 hours to departure). Frith (1974) reported a narrower range of inactivity. He maintained that sandhill cranes were active until midnight and that the period of least activity occurred from midnight to 0200 hr. Resting was the dominant activity of cranes during the evening and throughout the season. Similarly, Tacha et al. (1987) found resting to be the dominant nocturnal activity (95%) of sandhill cranes wintering in Texas, but they reported a seemingly high rate of resting activity (100%) among roosting cranes in Nebraska and Saskatchewan.

There was no seasonal trend in the overall activity patterns of roosting sandhill cranes. General activity patterns remained essentially unchanged from 19 March through 9 April (Fig. 10).

Weather appeared to have little influence on the nocturnal activity patterns of sandhill cranes except for a significant relation between flying and wind speed. Frith (1974) reported a similar effect of wind speed on flying activity. He maintained that during wind speeds in excess of 32 km/hr short flights within the flock were common.

Temperature appeared to have a slight influence on nocturnal activity. With cold temperatures there was decreased movement throughout the evening. Since mid- to late-night periods were the coldest periods, roosting birds may have obtained thermodynamic benefits by tucking their head under their wing and placing one foot against the body, the characteristic posture associated with resting.

Warm temperatures accounted for increased movement among roosting sandhill cranes. Higher rates of preening, walking, and flying coincided with unseasonably warm temperatures (over 8° C) on one night (3 April).

These differences in activity levels observed during warm and cold weather are a likely result of thermoregulation. It appears to be advantageous for sandhill cranes to conserve energy (i.e. rest) at low air temperatures. Thresholds for thermoregulation have been reported for waterfowl as well (Raveling et al. 1972; Wooly and Owen 1978; Albright et al. 1983; Gauthier et al. 1988; Paulus et al. 1988).

CONCLUSIONS

Departure times were earliest, arrival times latest, and the rate of departure and arrival were highest during the beginning of the staging season (9-12 March). However, during mid-(22 March-3 April) to late- (4-15 April) staging season there was a substantial change in the timing of roosting activity, as departure times were later, arrival times earlier, and departure and arrival rates were considerably lower. In addition, departure times also differed among sites.

Date of the staging season appeared to be the primary determinant of time of initial departure and arrival at the roost sites. Increasing time at the roost sites coincided with increased body fat deposition during the time spent within the Platte River Valley. Thus, it seems likely that the timing of roost activity is influenced by lipid accumulation. Similarly, the proportion of the flock departing the roost before sunrise was also influenced by the date of the staging season. The percentage of sandhill cranes departing before sunrise averaged 74% during the beginning of the staging season, then declined sharply to 17% from mid- to late-season.

Arrival and departure times were influenced by climatic factors. Departure times were positively correlated with fog and precipitation and negatively correlated with temperature, whereas arrival times were positively correlated with both cloud cover and temperature.

Activity patterns of roosting sandhill cranes varied through the night. Individuals were most active during periods 1 (time of arrival-2100 hrs) and 4 (0505 hrs-time of departure) and least active during periods 2 and 3 9 - 5 (2105-0505 hrs). Resting was the dominant activity of sandhill cranes; locomotory activity (i.e. walking and flying) was inconsequential. Thus, there was no evidence to suggest differential habitat use through the evening.

My findings that a small percentage (17%) of sandhill cranes left the roost prior to sunrise and that sandhill cranes were predominantly sedentary at night, supports to the validity and continued use of aerial photography to assess roost site selection. Data on roost site selection were obtained from aerial photographs from 21 March through 10 April 1989. The results from this study established that the percentage of the flock departing the roost before sunrise averaged 17% for the same period (22 March-15 April 1990). However, since my results were based on data from only a single field season, inferences should be made with this limitation in mind.

CHAPTER III

ROOST SITE SELECTION

INTRODUCTION

The impact of water resource development on the Platte River is well described (Kroonemeyer 1978; Williams 1978; Eschner et al. 1981; Kircher and Karlinger 1981; U.S. Fish and Wildlife Service 1981; Currier et al. 1985; Krapu et al. 1987; Lyons and Randle 1988; Sidle et al. 1989). The major impact has come from irrigation projects along the North Platte River (Krapu et al. 1982), which remove approximately 70% of the annual flow of the Platte River before reaching south central Nebraska (Kroonemeyer 1978). As a result, the channel width of the river has diminished (Lyons and Randle 1988), as much as 90% in some areas (Williams 1978). Concomitant with channel shrinkage, woody vegetation has encroached on thousands of hectares of former channel area (U.S. Fish and Wildlife Service 1981; Currier 1982), contributing to degradation of channel habitat. These changes have seriously altered habitat for numerous species of migratory birds in the Big Bend Reach of the Platte River (U.S. Fish and Wildlife Service 1985; Currier et al. 1985).

Considerable attention has been given to the impact of changing channel conditions on the midcontinent population of sandhill cranes (Grus canadensis) (Lewis 1977; Krapu 1979; U.S. Fish and Wildlife Service 1981) that congregate along the river during their annual spring migration from early March to mid-April. During this time approximately 400,000 (Solberg 1989) sandhill cranes use this area while en route to their breeding grounds in Canada, Alaska, and eastern Siberia (U.S. Fish and Wildlife Service 1981).

Although current habitat conditions appear to be suitable for the existing sandhill crane population, a major concern is the ongoing loss and degradation of existing roosting habitat (Krapu et al. 1982). The impact that water development may have on sandhill crane habitat is being assessed by the U.S. Bureau of Reclamation and the U.S. Fish and Wildlife Service. Both agencies have expressed interest in the use of a Habitat Suitability Index (HSI) model to assess habitat needs and to interpret the significance of existing habitat conditions along the Big Bend Reach of the Platte River. A draft HSI model for sandhill cranes (Armbruster and Farmer 1982) was developed by recognized crane experts, which identified three factors which characterize roosting requirements: (1) mean depth of water, (2) area of unobstructed view from the edge of a flock, and (3) presence or absence of disturbance factors within a defined distance from the channel.

In Nebraska, various facets of roosting habitat requirements have been studied (Frith 1974; Lewis 1974; U.S. Fish and Wildlife Service 1981; Krapu et al. 1982, 1984). However, these studies have not considered the influence of habitat availability in relation to habitat use. This study was undertaken to determine the influence of habitat availability, as well as habitat use, on the selection of roost sites by sandhill cranes, and to evaluate the performance of the Armbruster and Farmer (1982) HSI model.

STUDY OBJECTIVES

This study was designed with several objectives which focused on three habitat features that characterize the selection of roost sites by sandhill cranes.

Features included: (1) water depth, (2) unobstructed area, and (3) disturbance features.

Regarding water depth, I wished to:

(1) Describe the water depths used by sandhill cranes for roosting on the Platte River, Nebraska,

(2) Determine the influence of available water depths on the depths used by sandhill cranes,

(3) Determine any influence of related habitat features (such as channel width or discharge) on water depths used, and

(4) Determine the applicability of the depth component of the sandhill crane HSI model for application on the Platte River.

Relative to unobstructed area, I wanted to:

(1) Determine if flocks are distributed randomly with respect to distance from visual obstructions,

(2) Determine the influence of visual obstructions on roost site selection by sandhill cranes,

(3) Describe the unobstructed channel width used by sandhill cranes and determine if channel width has an effect on flock size, and

(4) Evaluate the overall performance of the unobstructed area variable of the sandhill crane HSI model.

Pertinent to disturbance features, I wished to:

(1) Determine if flocks are distributed randomly with respect to distance from various human disturbance features,

(2) Determine the potential zone of influence of various disturbance features on roost site selection by sandhill cranes, and

(3) Evaluate the disturbance potential for each of the disturbance features discussed in the sandhill crane HSI model.

STUDY AREA

The study area was located in south central Nebraska and encompassed a 36-km stretch of the Platte River beginning 4 km west of Shelton to Grand Island (Fig. 11). The study area was in Hall and Buffalo counties in the eastern half of the Big Bend Reach of the Platte River. All field measurements were in four 1.6-km reaches along the main channel of the Platte River.

The climate of the Platte River Basin is continental and is characterized by relatively low humidity, hot summers and severe winters. The mean monthly temperatures range from a low of -4.9° C in January to a high of 25.7° C during July (range 30.6° C). The total annual precipitation is seasonal, averaging between 47.5 and 60 cm, with approximately two thirds falling during the growing season from May-September (Stevens 1978).

Spring precipitation in Nebraska contributes to the Platte River Basin flow, but most of the flow is derived from spring runoff that originates as snowmelt in the Rocky Mountains (Eschner et al. 1981). Runoff streams flow into both the North Platte River and South Platte River which flow northeast and southeast, respectively, across the Great Plains to their confluence near North Platte, Nebraska. From the convergence of the North Platte River and South Platte River, the Platte River flows eastward across Nebraska along a 500-km course and empties into the Missouri River. The Platte River valley is underlain by Ogallala sedimentary rock of the Tertiary period and is covered by a Quaternary alluvium of clay, sand and gravel (Bose 1977).

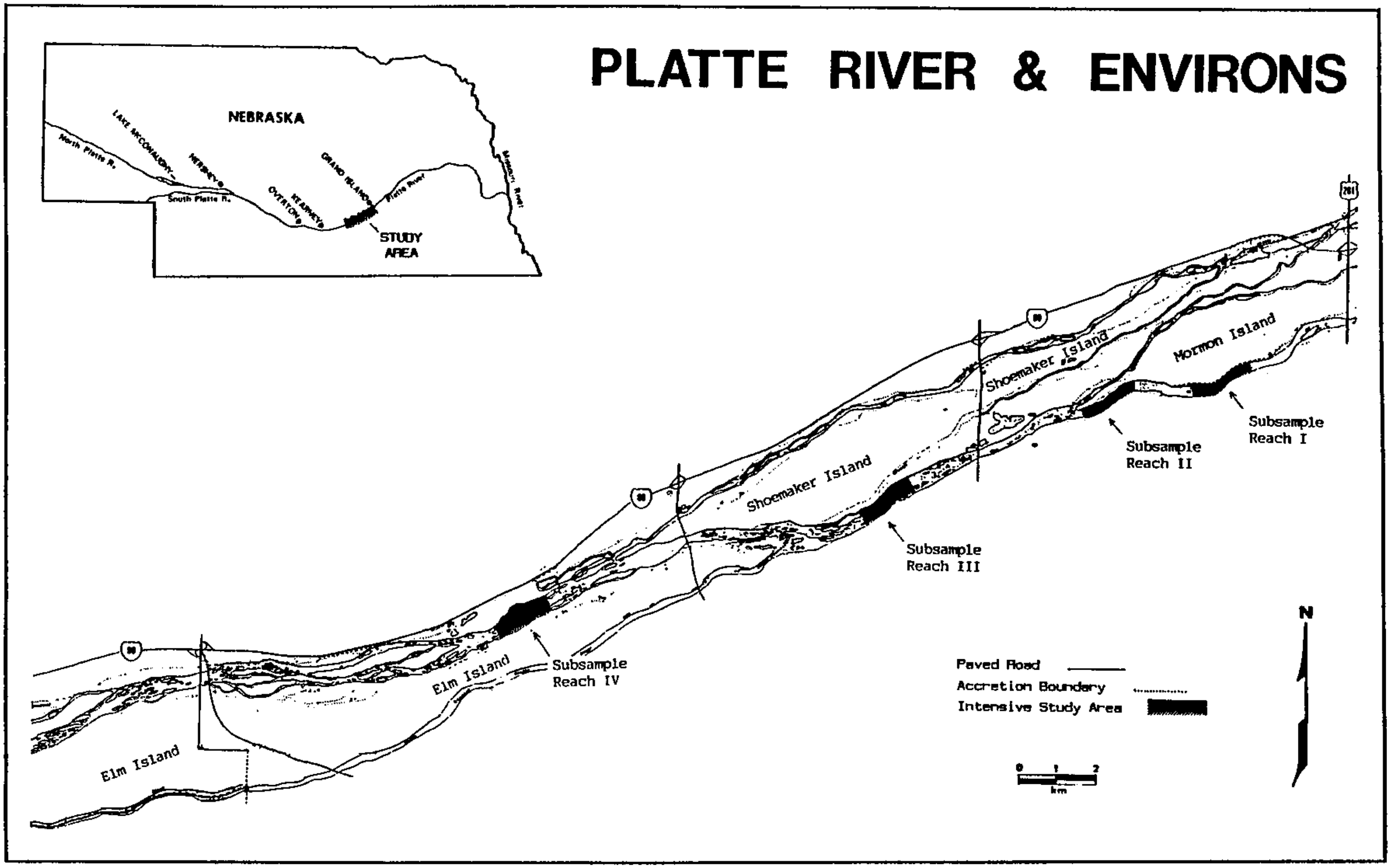


Fig. 11. Study Area and Location of Sample Reaches Sampled During Spring 1989.

As in most of the Platte River valley, the study area was characterized by numerous braided channels interspersed with hundreds of sandbars. Most of the land within and adjacent to the study area was in private ownership. Land use in the area was predominately agriculture and included approximately 60% cropland, 5% tame pasture, 20% native grassland, and 15% riparian woodland (Reinecke and Krapu 1979).

The riparian woodland located along the floodplain was comprised of open canopy cottonwood (Populus deltoides) forests with dominant understory species being red cedar (Juniperus virginiana), and rough-leaf dogwood (Cornus drummondii) (Currier 1982, U.S. Fish & Wildlife Service 1981). On low shrub islands and vegetated sandbars, peach-leaf willow (Salix amzgdaloides), coyote willow (S. exigua), and indigo bush (Amorpha fruticosa), were the dominant shrub species (Currier 1982; U.S. Fish & Wildlife Service 1981).

METHODS

Aerial photography was used to determine flock locations and delineate flock boundaries of roosting sandhill cranes along a 36-km stretch of the Platte River. Flights were flown on an opportunistic basis. Photography was restricted to mornings with less than 10% cloudcover and ceilings above 975 m. Flights were begun 30 minutes before sunrise because of the need to photograph sandhill cranes before they leave the roost in early morning. Light was adequate to permit photography 10-15 minutes before sunrise.

A Hasselblad 500 EL, 70 mm camera was used to photograph the study area. The camera was mounted in a standard camera hatch in a Cessna 172 fixed wing aircraft, and was equipped with an 80 mm focal length Zeiss lens. Exposures were made at 1/60 and 1/125 second at f2.8 using Kodak Tri-X 640

AFS Aerographic film. The camera was equipped with a 70 exposure back loaded with 5.5 m of film allowing 80 exposures.

The aircraft was flown at approximately 140 km/hr at an initial altitude of 790 m above ground level, for the first two flights. During the last two flights, the altitude was increased to 910 m above ground level. These altitudes provided a 0.48-km^2 and 0.64-km^2 coverage on each frame, respectively. Frame rate was controlled by an intervalometer, calibrated for 30% overlap, to provide continuous photographic coverage of the study area.

Shortly after landing, the film was custom processed by hand agitation in a single solution tank, varying time and developer temperature to obtain optimum development. Approximately 150 frames were exposed on each flight. The four reaches were located on the developed film and frames within each reach were examined under 8 x magnification to identify crane flocks. Frames containing flocks were enlarged to 41 x 51 cm (16 x 20 in) and printed on Kodak Poly contrast RC film. The film was stored for later analysis of visual obstructions and disturbance features.

Sampling was limited to four 1.6-km reaches referred to as Reach I, II, III, or IV. Each reach was marked on both sides of the river bank with 16, 1-m-square markers made of white cloth. The markers were 100 m apart at the edge of the river bank and were positioned in such a way that markers on the opposite sides of the channel were parallel to the channel. The markers enabled accurate scale measurements to be taken from photos and provided position reference for transects across the channel when sampling water depths. Aerial photographs covering each reach were used to determine the position of transects through flocks. Transects were positioned so that each studied flock on a photo was divided into general areas of equal size with two to five transects depending upon flock size. A flock was defined as a continuous distribution of birds or an aggregation of birds that was spatially independent of other birds separated by a distance > 20 m. Flocks usually occurred in configurations that appeared distinct from other flocks in the vicinity.

After transects were located on photographs they were measured and laid out on the ground in relation to marker locations using vinyl flagging placed on each side of the channel. Water depths were measured to the nearest 3 cm at 3-m intervals. Depth data were plotted on acetate laid over aerial photographs with delineated flock boundaries.

Reaches were sampled as soon as possible after each flight, always within 3 days. Staff gauges were placed in each reach to measure any changes in water level between the time each reach was photographed to the time it was sampled. Detectable changes in water level were recorded and later used to correct depth distributions.

Discharge was measured on each flight date at bridges in close proximity to the study reaches following the technique of Buchanan and Somers (1969). Discharge measurements for Reach I and II were taken at the south channel of the Highway 281 bridge and represented only a portion of the discharge by the Platte. Discharge was also measured in both the north and south channel at the Woodriver Bridge between Reach III and IV. Discharge in the south channel represented that in Reach III, while the combined discharge of both channels represented Reach IV.

In all, eight rolls of film (two from each flight) with over 1,200 exposed frames were obtained during the study season. Contact prints were made from each roll of film. Individual frames were cut out and glued onto posterboard to form a mosaic, providing a continuous coverage of the river channel. Scale was determined by comparing bridge segments and transect locations on the contact prints with measurements of these locations made on the ground. Scales between sites with measurements were estimated by averaging adjacent scale measurements. Scale estimates were made along 2- to 3-km segments of river. Photograph scales ranged from 1:8,681 to 1:10,334 for the first two flights, and 1:10,595 to 1:11,857 for the last two flights.

A binocular zoom microscope (1-4x) was used to identify flocks and delineate flock boundaries on the contact prints covered with acetate. Flocks were delineated and subsequently numbered on the acetate overlays on contact photos. The distance from the edge of each flock to the nearest visual obstruction was measured to the nearest 0.5 mm on the photos (ground distance = 4-6 m) using a drafting caliper. Visual obstructions as defined by the Armbruster and Farmer (1982) HSI model included vegetation, a river bank, or any other "visually solid" object > 1 m in height. Due to my inability to determine bank height or the height of woody vegetation from the photographs, I assumed that all river banks and woody vegetation was > 1 m in height.

Several variables were measured, including the minimum and maximum unobstructed channel width at each flock location as well as the surface area (relative size) of each flock. The surface area of each flock was determined by placing a gridded sheet of mylar (each grid square = 1.25 mm^2) over each flock and counting the number of squares within the corresponding flock boundaries.

Random points were plotted on contact photos to estimate the features of available habitat. Random points were determined by a series of random numbers identifying point coordinates on gridded overlay over the contact prints. Points outside the river channel were discarded. Only random points located

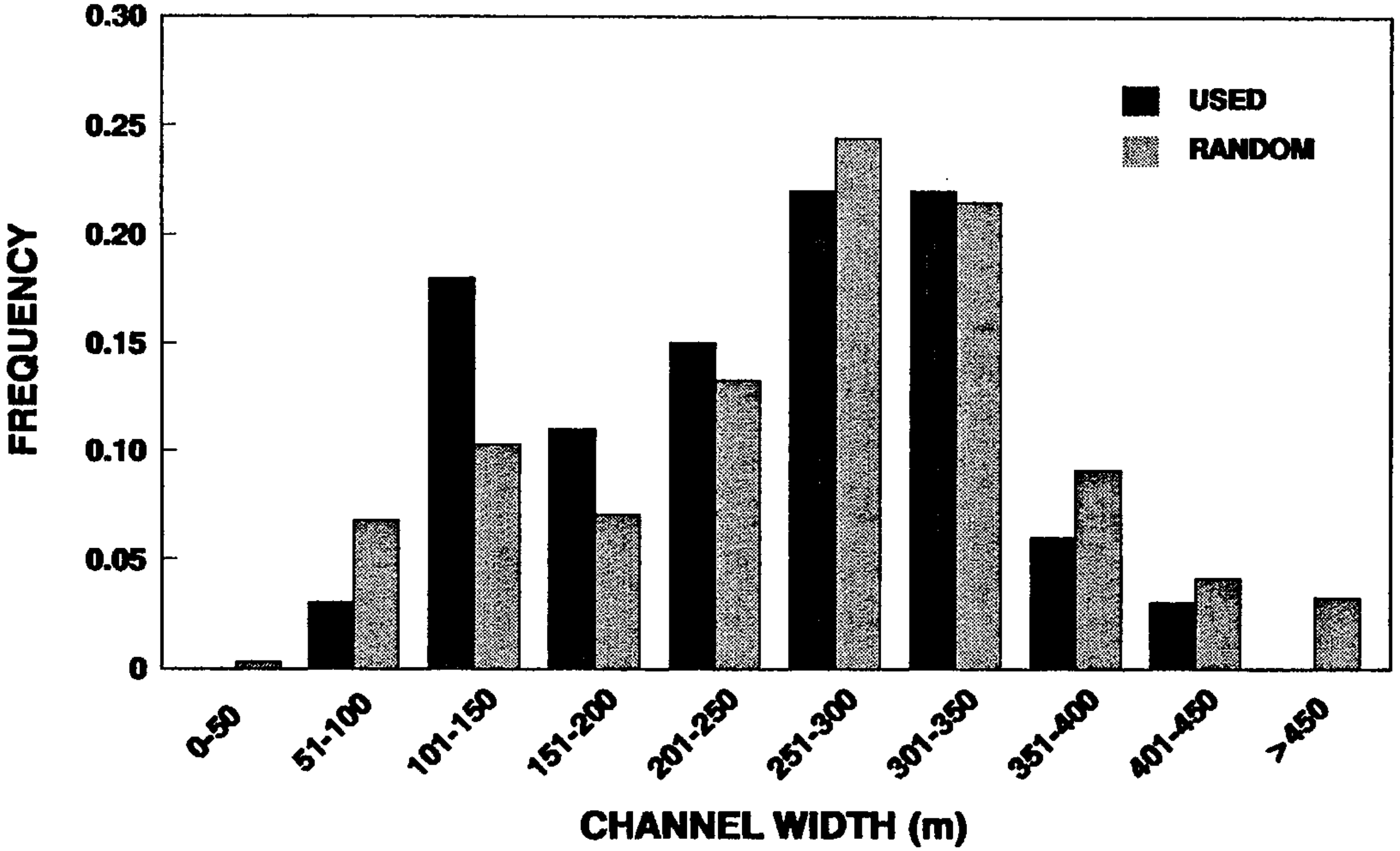


Fig. 26. Frequency Distributions of the Minimum Unobstructed Channel Width Used by Roosting Flocks (n = 285) and Available (Random) (n = 339). Comparisons Indicate a Difference Between the Distribution of Used and Available Channel Widths ($\underline{X}^2 = 24.74$, df = 9, $\underline{P} < 0.005$).

used by roosting flocks was 196 m (range = 34-445 m). Nearly 100% of the flocks were in channels with a minimum unobstructed channel width of > 50 m and over 97% and 80% of the flocks were in channels with a minimum unobstructed width of > 100 and > 150 m, respectively.

The mean relative flock size (surface area) was 3,883 m^2 (range = 19-55,354 m^2). There was no relation between flock size and the minimum unobstructed channel width (Fig. 27). Both large and small flocks were located in wide, as well as narrow channels. Comparisons of flock size between minimum and maximum unobstructed channel width indicated that large flocks (> 5,000 m^2) occurred simultaneously in both narrow and wide channels (Fig. 27).

HUMAN DISTURBANCE FEATURES

Paved Roads. Sandhill crane flocks were not distributed randomly with respect to distance from paved roads ($X^2 = 82.31$, df = 16, $P < 0.001$) (Fig. 28). Sandhill cranes showed avoidance of sites closer than 500 m, from the nearest paved road ($P < 0.05$) (Appendix Y), but used sites as close as 301-400 m (Fig. 28). Sites located 701-900 m from the nearest paved road were used more than expected ($P < 0.05$) (Appendix Y). The presence of a visual obstruction between roosting flocks and paved roads had an effect on the potential zone of influence ($P < 0.0007$) (Fig. 29). Sandhill cranes roosted a mean distance of 1260 m from the nearest paved road when a visual obstruction was present, but roosted a mean distance of 1575 m from the nearest paved road in the absence of visual obstructions.

Gravel Roads. There was a significant difference between the distribution of used sites and random locations relative to distance from gravel roads ($X^2 = 33.30$, df = 16, $P < 0.01$) (Fig. 30). Sandhill cranes showed avoidance of sites that were closer than 400 m from the nearest gravel road

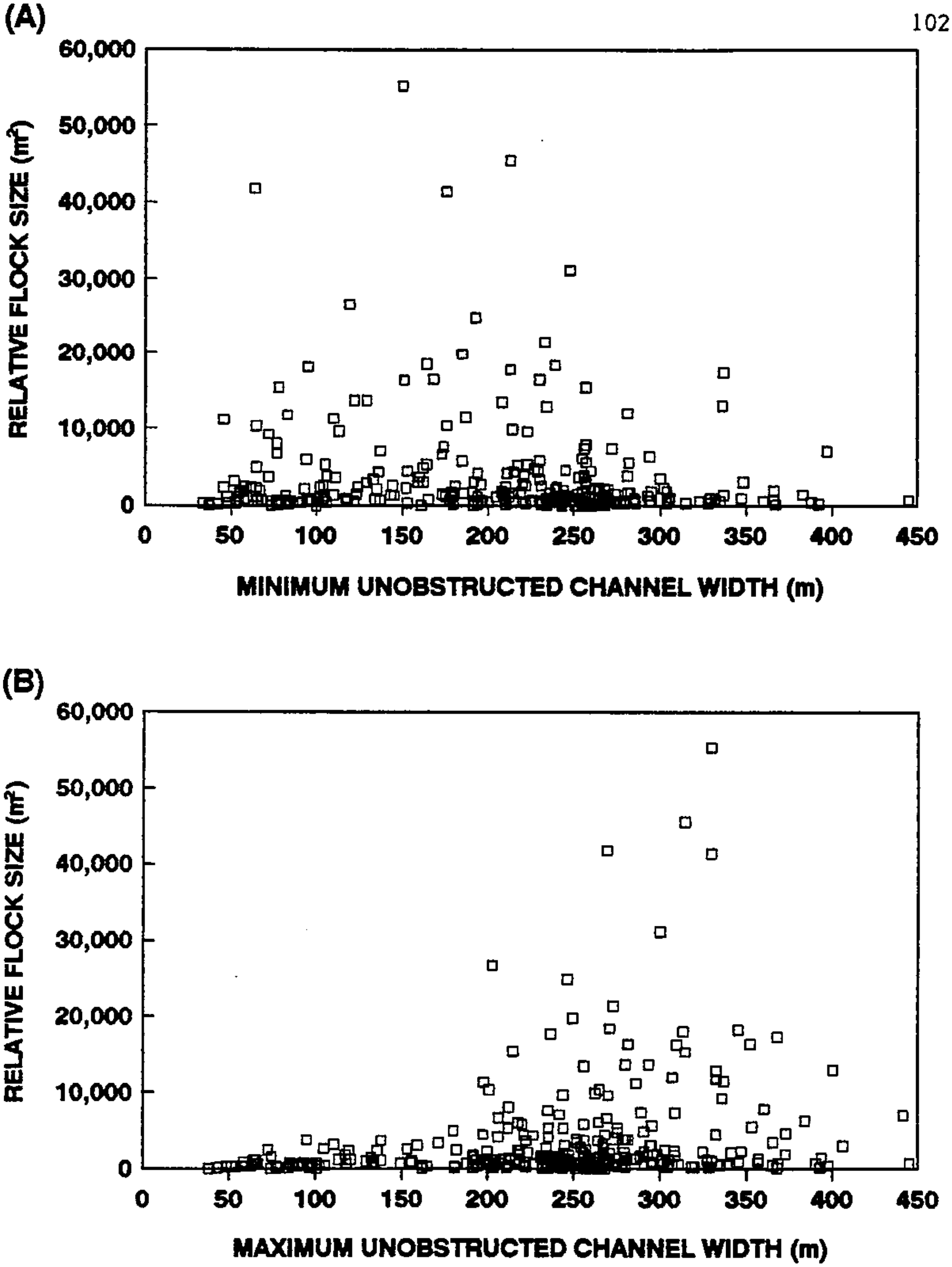


Fig. 27. Relationship Between Relative Surface Area of a Flock and Minimum (A) and Maximum (B) Unobstructed Channel Width for Roosting Flocks (n = 285) of Sandhill Cranes Along the Platte River between 21 March and 10 April 1989.

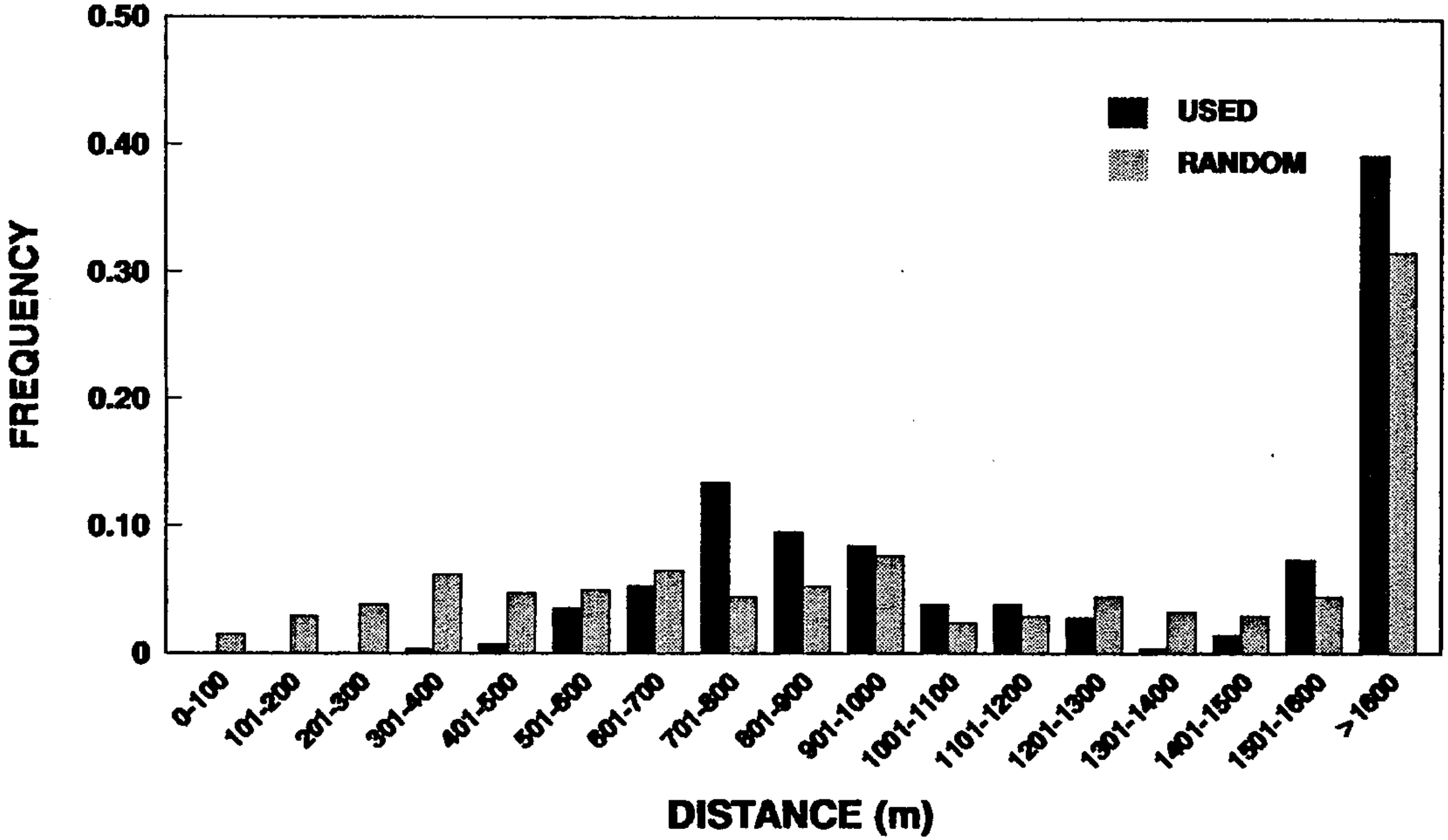


Fig. 28. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) (n = 285) and Random Points (n = 339) to the Nearest Paved Road. Comparisons Indicate a Significant Difference Between the Distribution of Used and Random Locations ($\underline{X}^2 = 82.31$, df = 16, $\underline{P} < 0.001$).

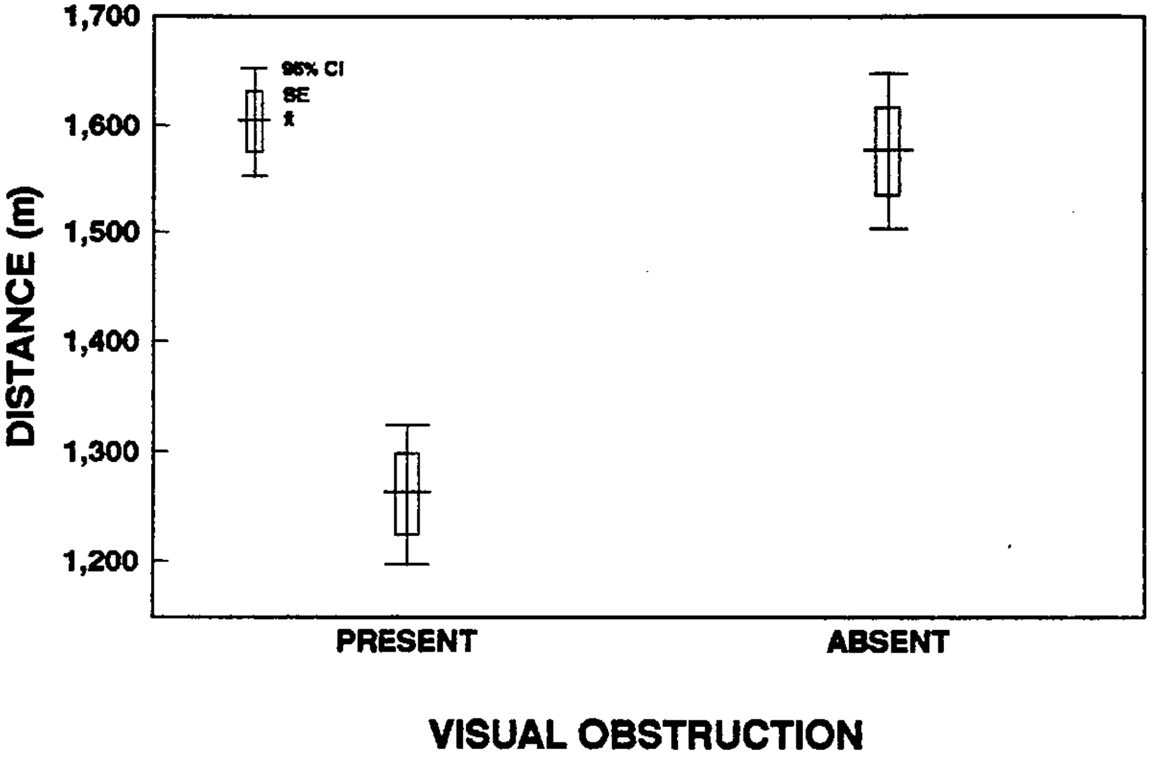


Fig. 29. Effect of Visual Obstruction on the Mean Distance Sandhill Cranes Roosted from a Paved Road.

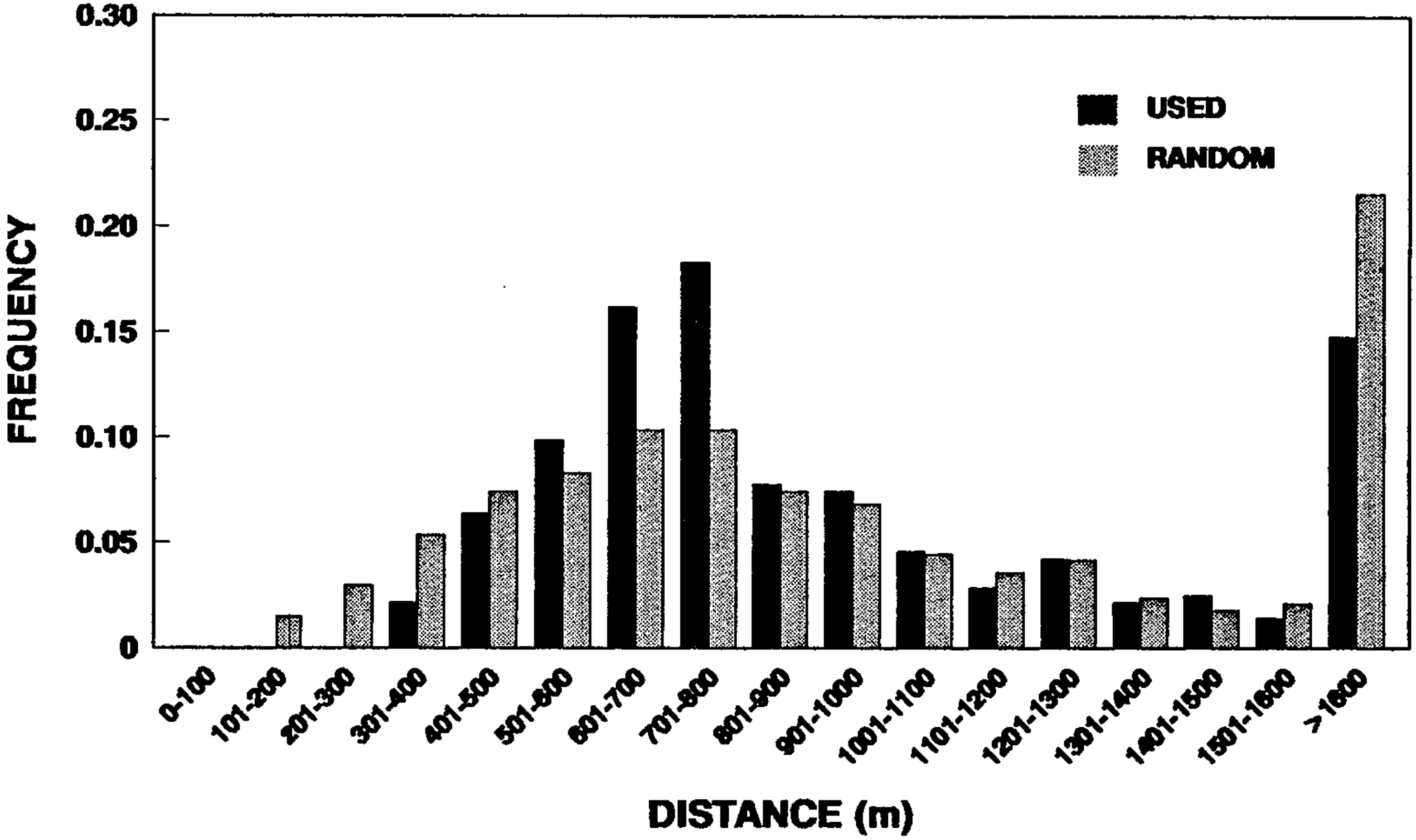


Fig. 30. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) (n = 285) and Random Points (n = 339) to the Nearest Gravel Road. Comparisons Indicate a Significant Difference Between the Distribution of Used and Random Locations ($\underline{X}^2 = 33.30$, df = 16, $\underline{P} < 0.01$).

($\underline{P} < 0.05$) (Appendix Y), but flocks were located as close as 301-400 m (Fig. 30). Sites that were 601-800 m from the nearest gravel road were used more than expected ($\underline{P} < 0.05$) (Appendix Y). The presence of a visual obstruction between a roosting flock and the nearest gravel road did not appear to reduce the disturbance potential created by gravel roads.

Private Roads. There was no significant difference between the distribution of random locations and those used relative to distance from the nearest private road ($\underline{X}^2 = 25.53$, df = 16, $\underline{P} > 0.05$) (Fig. 31). Sandhill cranes were located along sections of the river > 100 m from the nearest private road. The greatest frequency of flock locations were located at distances of 601-700 m from the nearest private road. The presence of a visual obstruction between a roosting flock and the nearest private road did not appear to affect the disturbance potential of private roads.

Urban Dwellings. Flocks were found to be randomly distributed with respect to distances from the nearest urban dwellings ($\underline{X}^2 = 12.92$, df = 16, $\underline{P} > 0.50$) (Fig. 32). Flocks were located at distances > 800 m from the nearest urban dwelling, but the presence of urban dwellings within the study area was restricted to a localized area directly south of Mormon Island. All urban dwellings were located > 800 m from the river.

Single Dwellings. There was a significant difference between the distribution of used and random locations relative to the distance to the nearest single dwelling ($\underline{X}^2 = 34.98$, df = 16, $\underline{P} < 0.01$) (Fig. 33). In general, sandhill cranes showed an avoidance for sites closer than 400 m from a single dwelling ($\underline{P} < 0.05$) (Appendix G). Sites 501-600 m from the nearest single dwelling were used more than expected ($\underline{P} < 0.05$). The presence of a visual obstruction

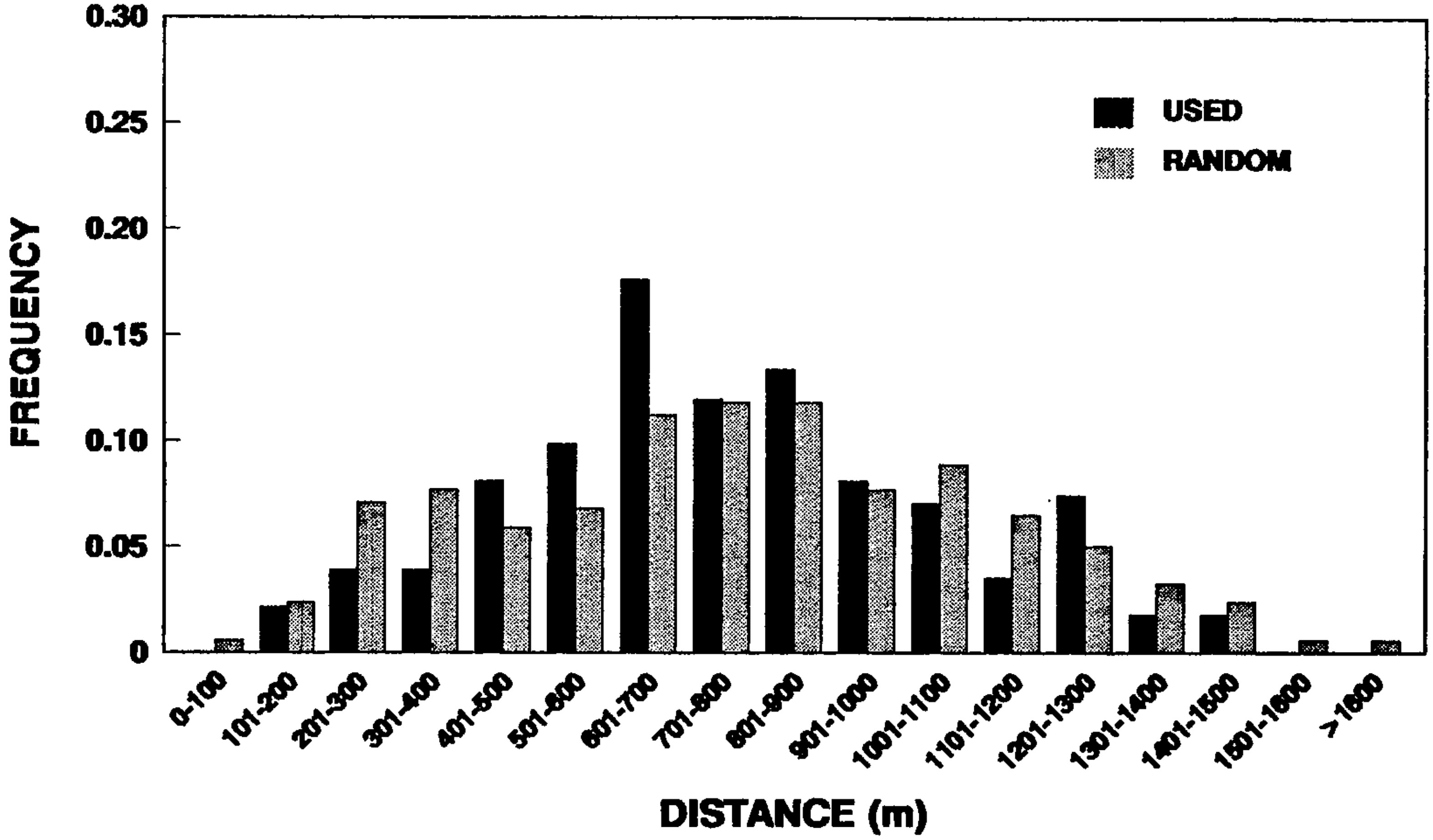


Fig. 31. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) (n = 285) and Random Points (n = 339) to the Nearest Private Road. Comparisons Indicate No Difference Between the Distribution of Used and Random Locations ($X^2 = 25.53$, df = 16, $\underline{P} > 0.05$). The Minimum Distance for Used Locations Represents the Maximum Disturbance Potential Created by Private Roads on Roosting Crane Flocks Along the Platte River.

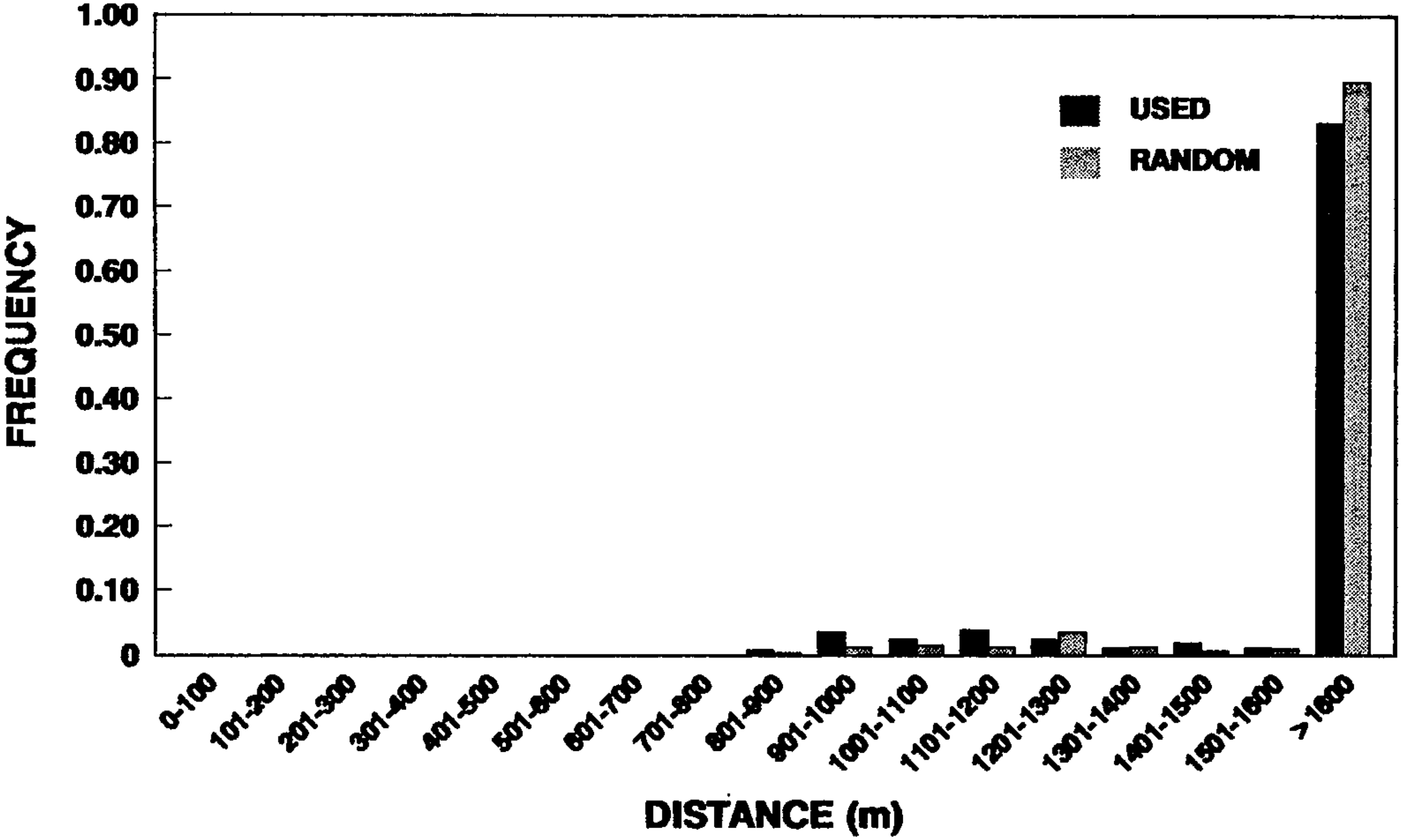


Fig. 32. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) (n = 285) and Random Points (n = 339) to the Nearest Urban Dwelling. Comparisons Indicate No Difference Between the Distribution of Used and Random Locations (X^2 = 12.92, df = 16, P > 0.50). The Minimum Distance for Used Locations Represents the Maximum Disturbance Potential Created by Urban Dwellings on Roosting Crane Flocks Along the Platte River.

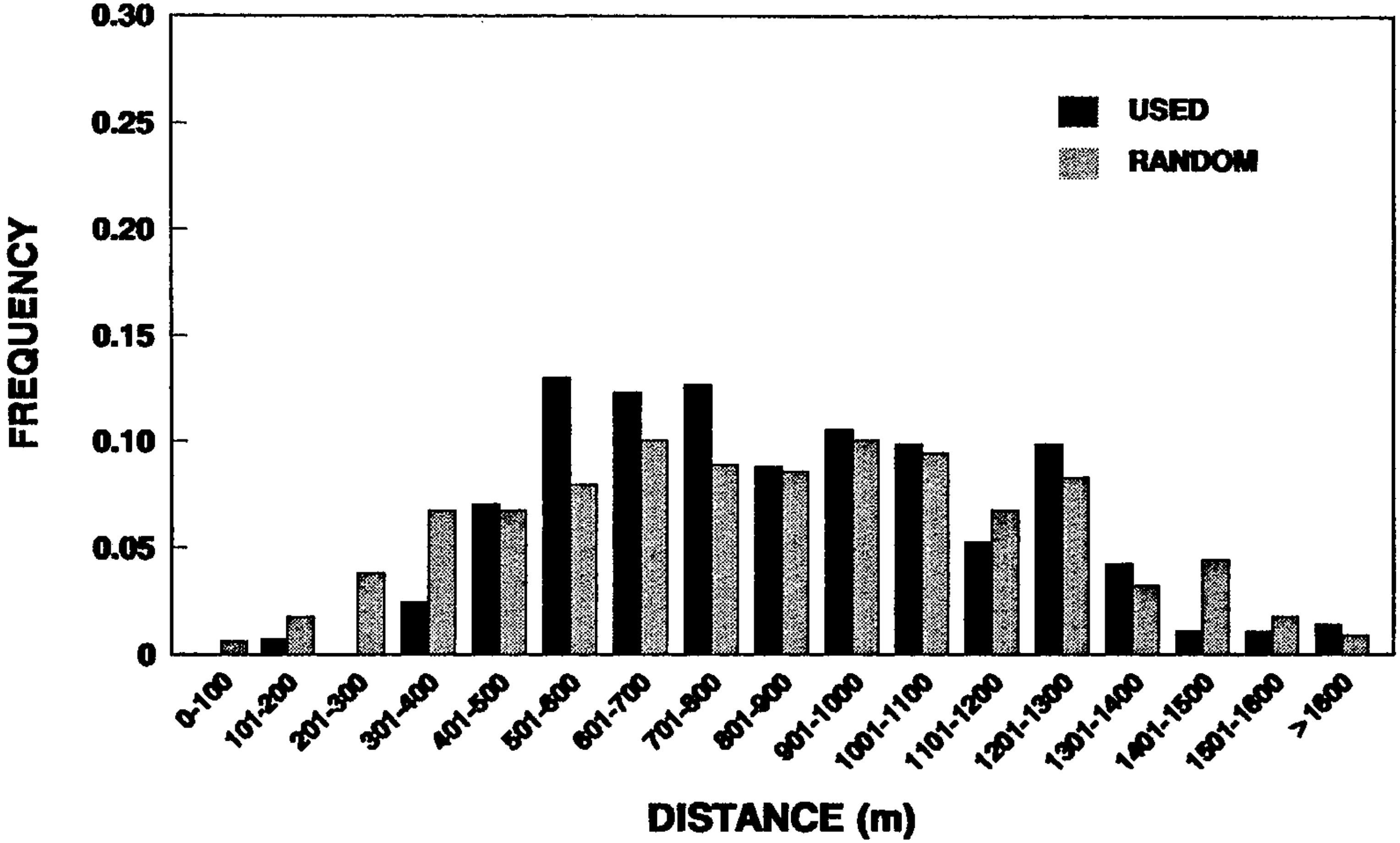


Fig. 33. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) (n = 285) and Random Points (n = 339) to the Nearest Single Dwelling. Comparisons Indicate a Significant Difference Between the Distribution of Used and Random Locations ($\underline{X}^2 = 34.98$, df = 16, $\underline{P} < 0.01$).

between a flock and the nearest single dwelling did not affect the disturbance potential created by single dwellings.

Gravel Pits. There was no significant difference between the distribution of used and random locations relative to the distance from gravel pits ($\underline{X}^2$ = 23.00, df = 16, $\underline{P} > 0.10$) (Fig. 34). Sandhill cranes used sites > 100 m from the nearest gravel pit. The presence of a visual obstruction between a roosting flock and the nearest gravel pit did not seem to reduce the disturbance potential of gravel pits.

Commercial Development. There was no significant differences between the distribution of flock locations and those available relative to distances from commercial development ($\underline{X}^2$ = 22.83, df = 16, $\underline{P} > 0.10$) (Fig. 35). Sites available for roosting were at distances > 400 m from the nearest commercial development, but nearly all commercial development was located > 1.6 km from the river.

Railroads. There was no significant difference between the distribution of flock locations and locations that were generally available relative to distance from the nearest railroad ($\underline{X}^2$ = 22.40, df = 16, $\underline{P} > 0.10$) (Fig. 36). Sandhill cranes roosted at sites located > 600 m from a railroad bridge, but only one railroad line was located within the study area. Potential roosting sites were available adjacent to the railroad bridge.

Highlines. There was no significant difference in the distribution of distances to the nearest highlines between random locations and those used by crane flocks ($\underline{X}^2$ = 16.64, df = 16, $\underline{P} > 0.25$) (Fig. 37). Sandhill cranes only used areas of the river located > 200 m from a highline, but there was only a single distribution line that intersected the study area.

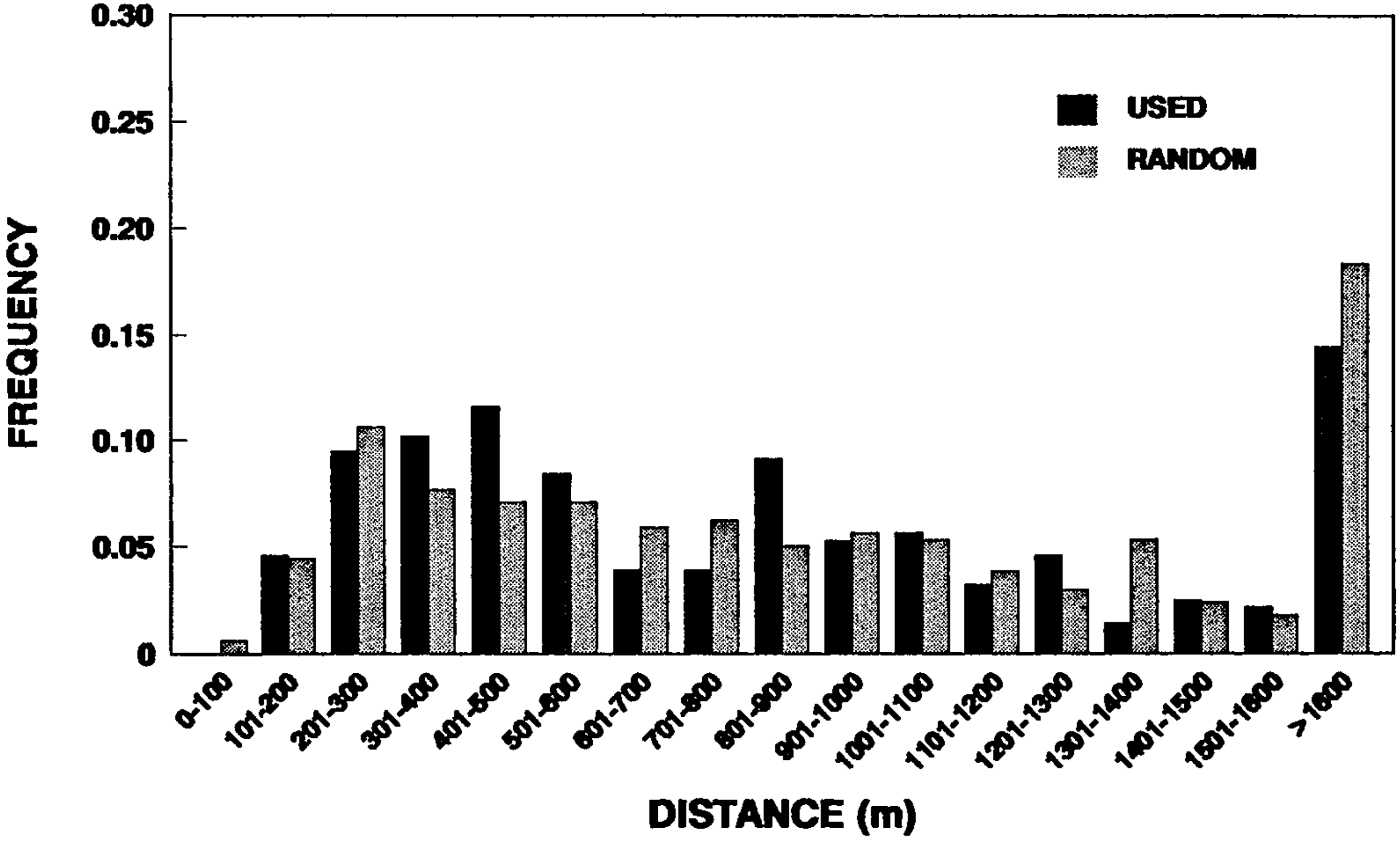


Fig. 34. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) (n = 285) and Random Points (n = 339) to the Nearest Gravel Pit. Comparisons Indicate no Significant Difference Between the Distribution of Used and Random Locations ($\underline{X}^2 = 23.00$, df = 16, $\underline{P} > 0.10$). The Minimum Distance for Used Locations Represents the Maximum Disturbance Potential Created by Gravel Pits on Roosting Crane Flocks Along the Platte River.

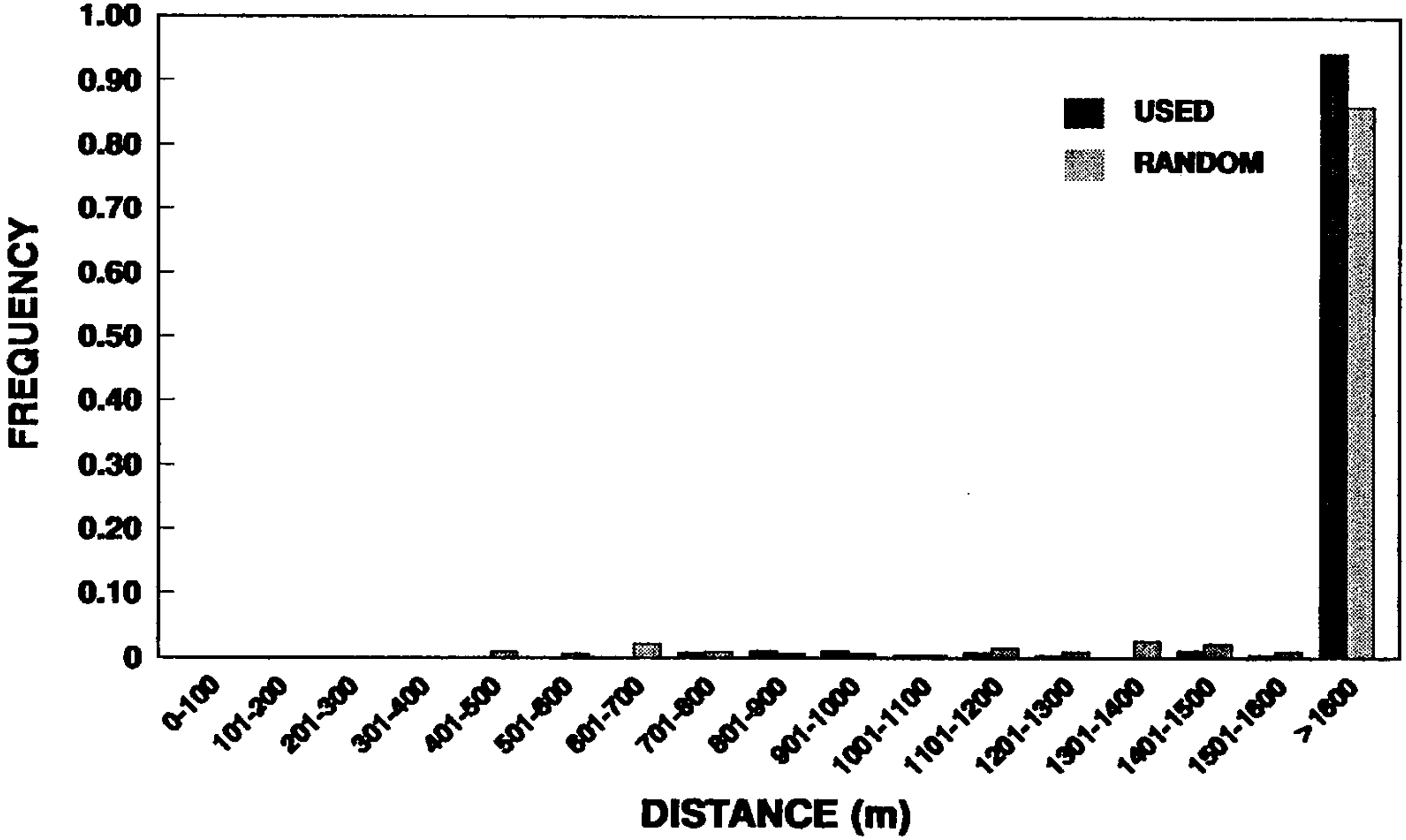


Fig. 35. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) (n = 285) and Random Points (n = 339) to the Commercial Development. Comparisons Indicate No Difference Between the Distribution of Used and Random Locations ($\underline{X}^2 = 22.83$, df = 16, $\underline{P} > 0.10$). The Minimum Distance for Used Locations Represents the Maximum Disturbance Potential Created by Commercial Development on Roosting Crane Flocks Along the Platte River.

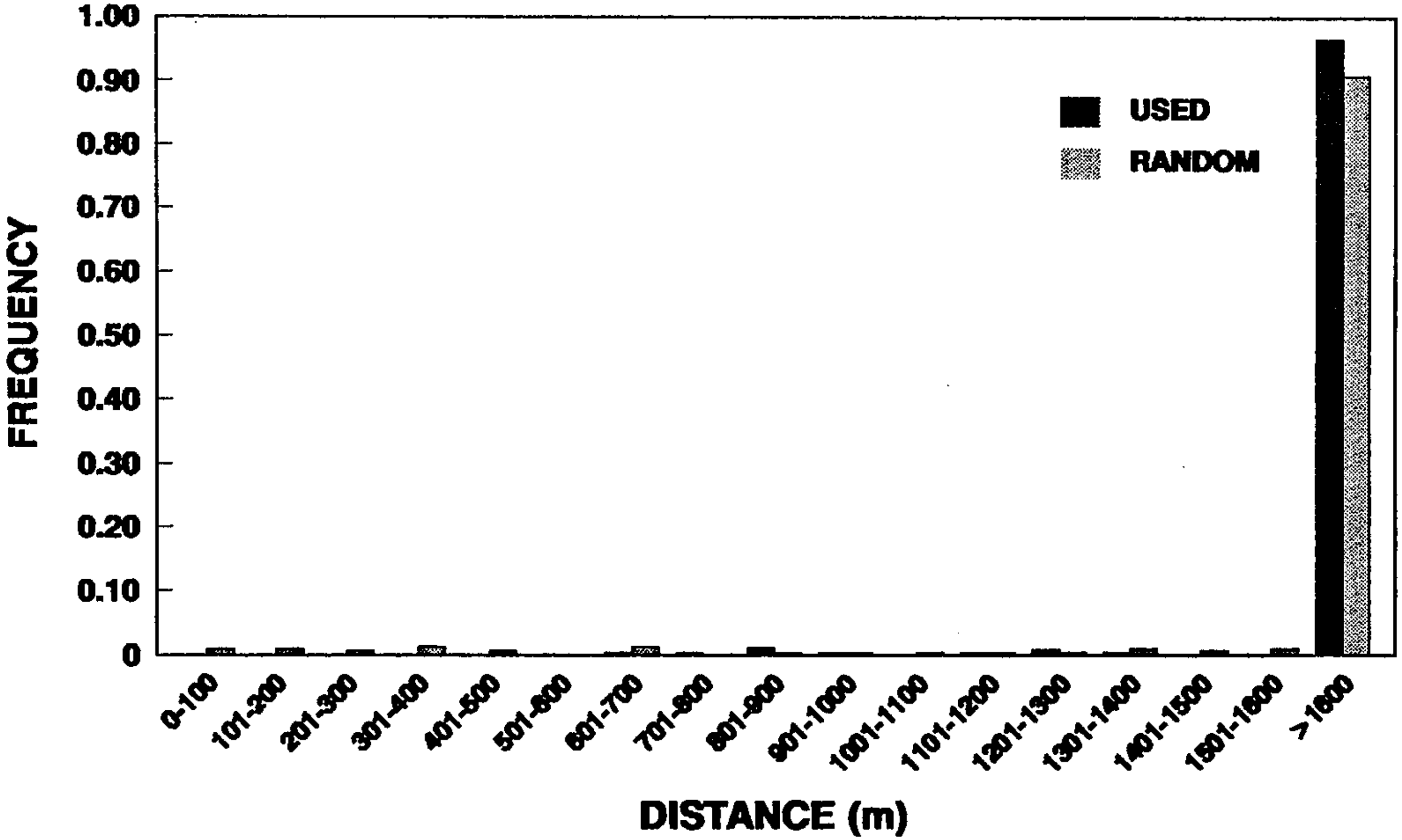


Fig. 36. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) ($n = 285$) and Random Points ($n = 339$) to the Nearest Railroad. Comparisons Indicate No Difference Between the Distribution of Used and Random Locations ($\underline{X}^2 = 22.40$, df = 16, $\underline{P} > 0.10$). The Minimum Distance for Used Locations Represents the Maximum Disturbance Potential Created by Railroads on Roosting Crane Flocks Along the Platte River.

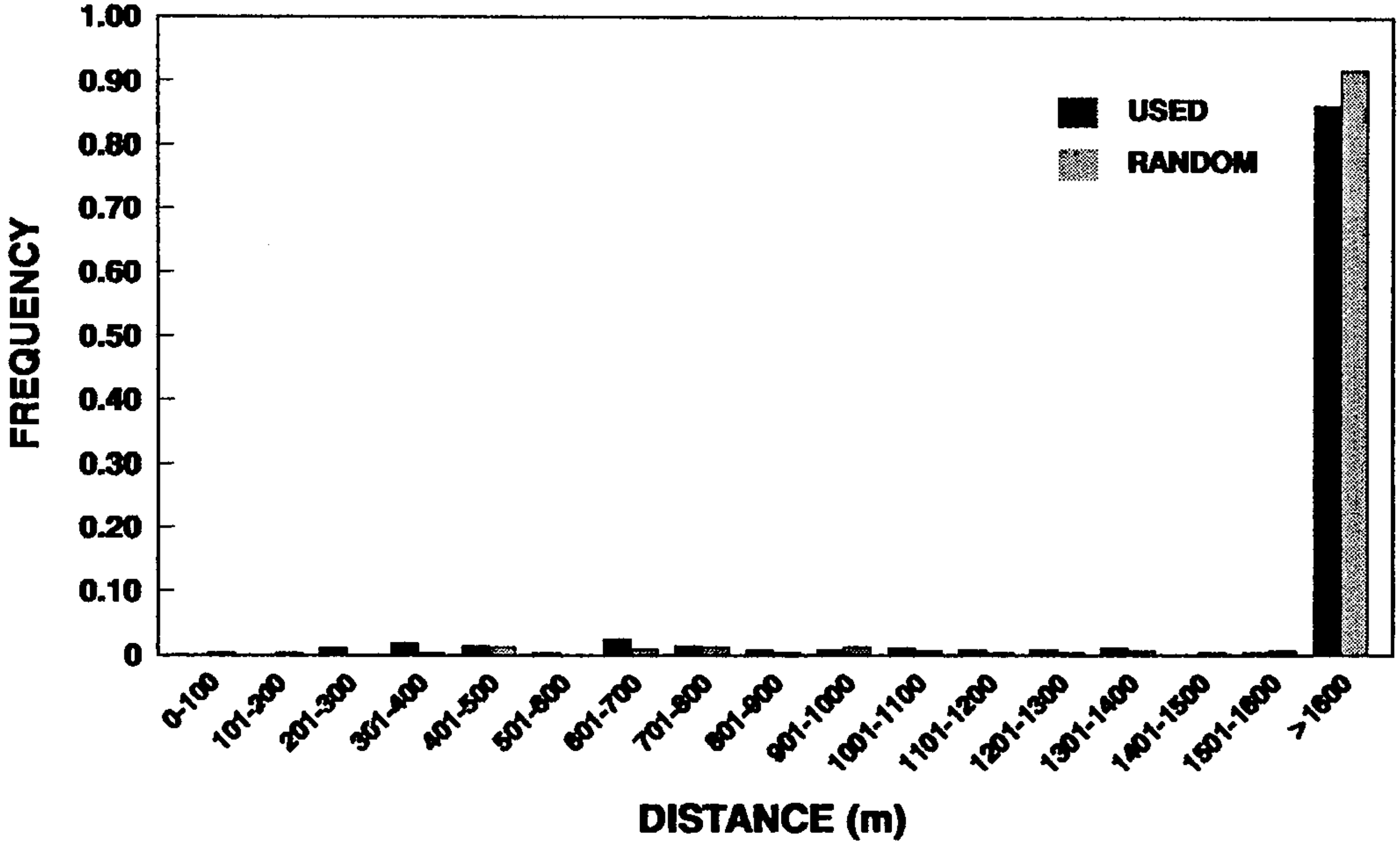


Fig. 37. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) (n = 285) and Random Points (n = 339) to the Nearest Highline. Comparisons Indicate No Difference Between the Distribution of Used and Random Locations ($X^2 = 16.64$, df = 16, $P > 0.25$). The Minimum Distance for Used Locations Represents the Maximum Disturbance Potential Created by Highlines on Roosting Crane Flocks Along the Platte River.

Bridges. Sandhill crane flocks were not distributed randomly with respect to distance from bridges ($X^2 = 55.13$, df = 16, $P < 0.001$) (Fig. 38). They showed avoidance of sites closer than 400 m from the nearest bridge ($P < 0.05$) (Appendix Z). Similarly, they used sites > 400 m from the nearest bridge. The presence of a visual obstruction between a roosting flock and the nearest bridge did not appear to affect the disturbance potential created by bridges. Bridges intersected the river at three locations within the study area and were generally 8-9-km from one another. Habitat was available for use adjacent to and under bridges.

DISCUSSION

DEPTH DISTRIBUTIONS. This study indicated that sandhill cranes select water depths of 1-13 cm for roosting, since these depths were used significantly more than expected. Previous descriptions of the selection of water depths were in general agreement with my observations. Latka and Yahnke (1986) developed a predictive model for sandhill crane roosting habitat and stated that the majority were found in depths between 0 and 12 cm, which is presumably the optimal depth for roosting. Similarly, Frith (1986) suggested a water depth of 2-15 cm as being optimum for roosting sites.

Currier et al. (1985) and Anderson and Hubert (1988) reported a slightly deeper range of depths from 10-15 cm as optimum for roosting. Lewis (1974) suggested that roost sites be characterized by depths 10 to 20 cm and Folk (1989) reported an even greater range of depths used for roosting from 0.1 to 21.0 cm for sandhill cranes along the North Platte River in Nebraska.

The optimum range of water depths for roosting (10.2-20.3 cm) stated in the HSI model of Armbruster and Farmer (1982) corresponds to the depth

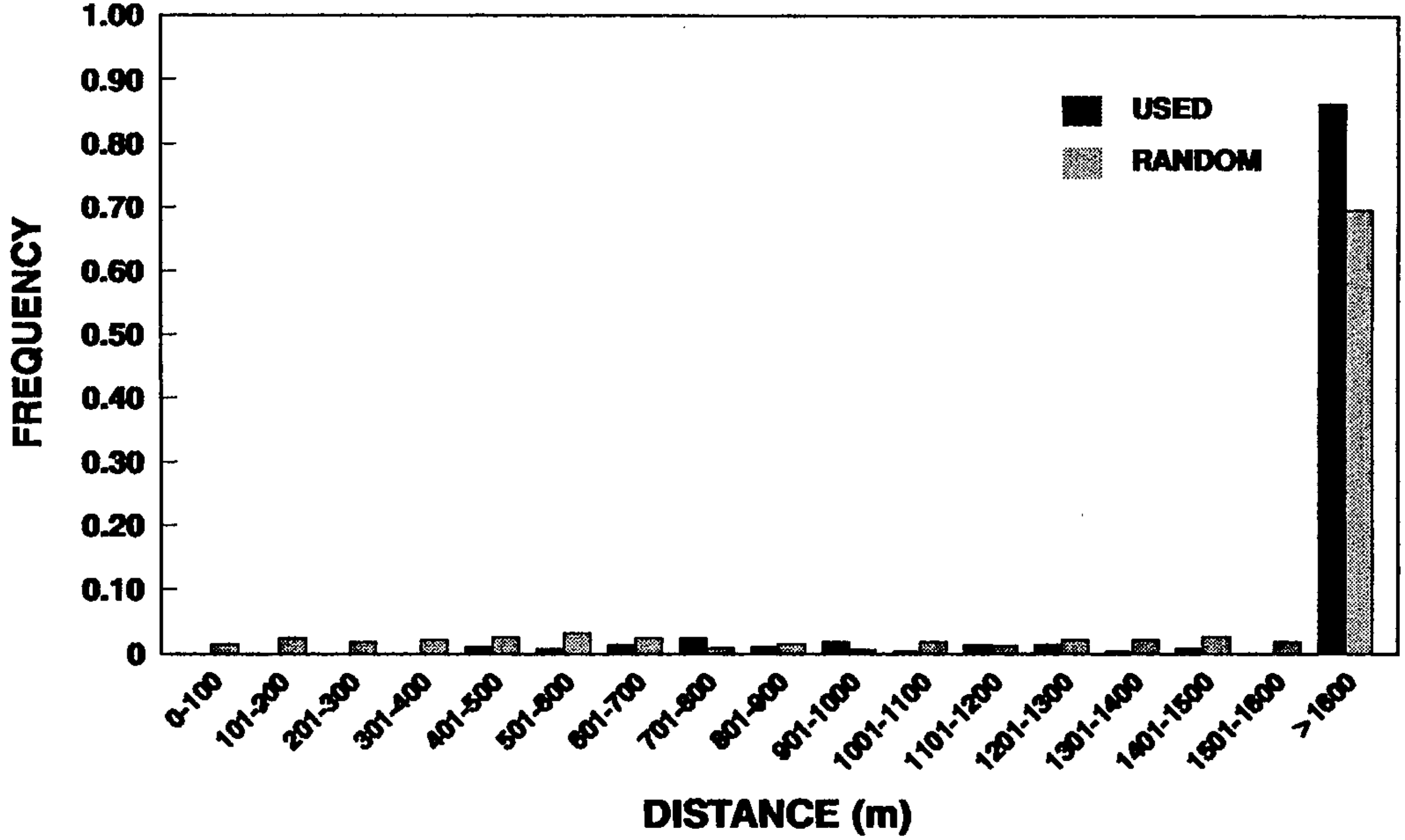


Fig. 38. Frequency Distributions of Distances from the Edge of a Roosting Flock (Used) (n = 285) and Random Points (n = 339) to the Nearest Bridge. Comparisons Indicate a Significant Difference Between the Distribution of Used and Random Locations ($\underline{X}^2 = 55.13$, df = 16, $\underline{P} < 0.001$).

criterion of Lewis (1974). However, the results from this study provide evidence for the selection of depths 1-13 cm and avoidance of depths > 19 cm.

Although this study was conducted during a single year, sandhill crane habitat use was studied over a wide range of flow conditions. Frequency histograms for habitat use and habitat selection indices provided differing results between the beginning and end of the period of study (Figs. 18 and 21). Histograms for habitat use were more similar than habitat selection indices, which consider differences in availability. Despite a highly significant change in the availability of water depths (Appendix T) and over a 50% reduction in discharge over the period of study, only slight differences were detected in the overall use of specific water depths. A disproportionately high use of exposed sandbars on 21 March contributed to the difference in habitat use between the beginning and end of the study season (Appendix T). Selective use of sandbars during this time was attributed to the accumulation and movement of slush ice along the Platte River, which forced many birds onto exposed sandbars.

The fact that habitat use remained the same despite a change in habitat selection, suggests that selection indices more strongly reflected changes in habitat availability than habitat preference. If habitat selection had reflected habitat preference then habitat selection indices would have been more similar between the beginning and end of the study period.

VISUAL OBSTRUCTIONS. This study indicated that sandhill cranes will not roost closer than 5 m from a visual obstruction and that distances from 11 to 25 m are the most frequently used. This is in contrast to the HSI model of Armbruster and Farmer (1982) which stated that sandhill cranes require at least 25 m of unobstructed view before they will use a channel for roosting. Latka and Yahnke (1986) reported that cranes did not roost < 15 m from the bank. Folk (1989) suggested that sandhill cranes preferred to roost > 25 m from a visual obstruction, but he observed roosting as close as 4 m from a visual obstruction. The HSI model of Armbruster and Farmer (1982) considers a visual obstruction as vegetation, a stream bank or any other visually solid object > 1 m in height. An assumption of the HSI model was that all forms of visual obstructions have equal weight in terms of influencing the potential location of a roost site. However, my results indicate that various forms of visual obstructions have different impacts on roost site selection. Overall, vegetated islands have little influence on the selection of roost sites, whereas vegetated banks have greater influence.

It is generally believed that sandhill cranes maintain an optimum distance from a visual obstruction in order to increase their security from terrestrial predators (i.e. Canids) (Armbruster and Farmer 1982). This suggestion is evidenced by the fact that the majority of flocks are located in closer proximity to vegetated islands than to unvegetated or vegetated banks.

It is logical to assume that channel morphology may also be a factor influencing the distribution of roosting areas relative to banks or islands. This assertion is supported by observations from my depth measurements which suggest that water depths near banks are deeper than depths near islands due to the undercutting action of current. Thus, sites near islands may contain a greater proportion of suitable roosting depths than sites adjacent to banks.

<u>CHANNEL WIDTH</u>. Sandhill cranes selectively used channels 100-200 m wide, while channels narrower than 100 m were avoided. Nearly 100% of the roosting sandhill crane flocks were located in channels with an unobstructed channel width > 50 m and over 80% were located in channels > 150 m wide. Wide channels potentially provide more space for roosting sandhill cranes, more

security from predators, and more available water depths to choose from. However, since channel width was evaluated independently of channel depth, it was possible that use of narrow channels (< 100 m wide) was limited not so much by a requirement for wider channels, but by deeper water that flows through these channels (Latka and Yahnke 1986).

My findings corroborate the results of Krapu et al. (1984) who reported that over 99% of all roosting sandhill cranes were in unobstructed channels over 50 m wide and almost 70% were in channels > 150 m wide. Similarly, the Bureau of Reclamation (1989) suggested that sandhill cranes showed a preference for channel widths > 150 m. In contrast, data from nighttime aerial thermography by Pucherelli (1988) suggested that almost half of all roosts were in channels < 150 m wide and that the greatest proportion of roosts were in channels 51-150 m wide.

Folk (1990) studied roosting along the North Platte River in Nebraska and reported a channel width criterion that was different from this study. He reported that 82% of the roosts were in channels > 48 m wide and 18% were in channels from 16-47 m wide.

HUMAN DISTURBANCE. My study demonstrated that human disturbance features influence selection of roost sites by sandhill cranes. In general the greatest disturbance potentials were attributed to highways and railroads. Comparisons were made for the types of disturbances influencing use of potential roost sites by sandhill cranes and the associated zones of influence between the results from this study and the human disturbance variables presented in the HSI model of Armbruster and Farmer (1982).

Paved Roads. Sandhill cranes roosted as close as 301-400 m to a paved road, but showed a significant avoidance for areas closer than 500 m from a paved road ($\underline{P} < 0.05$). The HSI model stated that the potential zone of influence for paved roads was 400 m (Table 13). My study indicated that the presence of visual obstructions between a roosting flock and a paved road had a strong effect on reducing the overall disturbance potential of paved roads (Fig. 29).

Gravel Roads. The HSI model indicated that the zone of influence for gravel roads was only half that for paved roads (Table 13). My study showed that sandhill cranes were roosting in areas located > 300 m from the nearest gravel road, but avoided areas closer than 400 m from the nearest gravel road ($\underline{P} < 0.05$). It is logical to assume that the presence of a visual obstruction between a flock and the nearest gravel road would have a similar effect as with paved roads in reducing the disturbance potential. However, there was no evidence to suggest that the presence of a visual obstruction between a flock and gravel road had any influence in reducing the disturbance potential of gravel roads.

Private Roads. There were also differences between this study and the HSI model for distances offered for the zone of influence for private roads (Table 13). Sandhill cranes roosted along sections of the river that were over two times as far from the nearest private road than was suggested by the HSI model. It is suspected that the observed differences between the disturbance potential created by either gravel or paved roads and private roads were due to differences in the frequency of use. Private roads were used infrequently, whereas paved and gravel roads had a substantially higher frequency of use. There was no evidence to suggest that the presence of a visual obstruction between a flock and private road had any impact on reducing the overall disturbance potential of private roads.

Table 13. Comparisons Between the Armbruster and Farmer (1982) HSI Model and the Results from This Study for Types of Disturbances Influencing Use of Potential Roost Sites by Sandhill Cranes and Their Associated Zones of Influence.

	Potential Zone of Influence (m)	
Type of Disturbance	HSI Model	This Study
Paved road	400	500
Gravel road	200	400
Private road	40	100
Urban dwelling	800	800
Single dwelling	200	400
Railroad	400	600
Commercial development	800	700
Highlines	40	200
Bridges	400	400

Urban Dwellings. The zone of influence offered for urban dwellings was identical between this study and those stated by the HSI model. Both suggested that cranes will not roost < 800 m from an urban dwelling. This may be misleading, since the data from this study indicate that there were no available locations < 800 m from the nearest urban dwelling for use as roost sites. That is, sandhill cranes were located > 800 m from the nearest urban dwelling not because of the disturbance potential created by urban dwellings but because all urban dwellings were located > 800 m from the river.

Single Dwellings. The overall disturbance potential created by single dwellings was not easily explained. The HSI model states that sandhill cranes will not roost closer than 200 m from the nearest single dwelling (Table 13). The results from this study indicate that sandhill cranes were roosting as close as 101-200 m from the nearest single dwelling, but generally showed an avoidance for areas closer than 400 m from the nearest single dwelling ($P < 0.05$). This lack of continuity suggests that the presence of a visual obstruction between a flock and a single dwelling may have an effect on which areas are actually selected by sandhill cranes or that the actual disturbance potential created by single dwellings is confounded by other factors (i.e. private roads, gravel roads, etc.).

Railroads. The zone of influence for railroads differed by as much as 200 m between this study and the HSI model (Table 13). In general, sandhill cranes avoided sites located < 600 m from the nearest railroad.

Commercial Development. Sandhill cranes were located in areas that were as much as 100 m closer to the nearest commercial development than was suggested by the HSI model (Table 13). The difference in the zone of influence was not substantial enough to speculate on possible explanations as to why differences may exist.

Highlines. The most substantial difference between disturbance potentials observed in this study and those stated in the HSI model were for highlines (Table 13). Sandhill cranes in this study were found to roost at a distance > 200 m from a highline. In contrast, the HSI model suggests that sandhill cranes will roost as close as 40 m from a highline. Other researchers have studied the effects of powerlines on sandhill cranes near my study area. Anne Morkill (University of Wyoming, Laramie, personal comm.) estimated that sandhill cranes in her study sites during 1989 were roosting > 150-200 m from a powerline. She indicated that sandhill cranes fly over powerlines and rarely fly under them.

Bridges. The zone of influence suggested by the HSI model and this study for bridges was identical (Table 13). Both suggested that cranes will not use areas of the river located < 400 m from the nearest bridge. In general, sandhill cranes showed a significant avoidance of areas closer than 400 m from a bridge ($P < 0.05$).

Recreational Areas. Recreational areas were considered a significant disturbance potential by the HSI model. However, there were no recreational areas < 1.6 km from the river. The majority of these areas were located west of the study area. Therefore, comparisons could not be made for the disturbance potential of these areas between the results of this study and the HSI model.

Gravel Pits. The disturbance potential presented by gravel pits was assessed in this study, however, the HSI model did not specifically address gravel pits as a potential disturbance variable, therefore comparisons could not be made. It is nevertheless possible that the HSI model may have formerly included gravel pits in one of the other categories of disturbance, such as commercial development, for example. In general, the results from this study indicate that gravel pits posed one of the least severe disturbance potentials to roosting sandhill cranes.

There is little literature which objectively describes the zones of influence exerted by various human disturbance features on the selection of roost sites by sandhill cranes along the Platte River. Folk (1989) studied roost site selection by sandhill cranes along the North Platte River and suggested that riparian forest along the river provided a visual barrier against most types of potential disturbances. He reported that sandhill cranes roosted in sections of the river that were as close as 80 m from a bridge. This was in contrast to the results of this study which indicated that sandhill cranes roosted in sections of the river that were > 400 m from the nearest bridge.

Currently there is no literature which describes the effect that various disturbance features have on the selection of roost sites by sandhill cranes along the Platte River. It is felt that the results from this study provide an objective description of potential zones of influence exerted by various disturbance features and the effect these features have on roost site selection by sandhill cranes along the Platte River.

<u>EVALUATION OF THE HSI MODEL</u>. An assessment of each of the HSI model variables described by Armbruster and Farmer (1982) compared to the results from this study suggests that there were differences between depth criterion for roost sites along the Platte River. The model suggests that optimum depths include the range from 10.2 to 20.3 cm. Conversely, the results from this study indicate that optimum depths for roosting include the range from 1 to 13 cm. With this in mind, it is suggested that the Armbruster and Farmer

(1982) HSI model be modified to include shallower depths (1-10 cm) as optimum to the exclusion of deeper depths (> 13 cm).

This study corroborates the channel width criteria proposed by the HSI model. According to the model, optimum conditions for roosting occur when there is a minimum unobstructed channel width > 150 m. The results from this study indicate that sandhill cranes selectively used channels 100-200 m wide and that 80% of the flocks sampled were located in channels with a minimum unobstructed width > 150 m.

There was a marked difference between this study and the HSI model for the distance to nearest visual obstructions. The model states that cranes require a distance of > 25 m of unobstructed view in all directions before they will use a channel for roosting. In contrast, the results from this study indicate that distances from 11 to 25 m receive the highest frequency of use by cranes. Therefore, it is suggested that the HSI model be amended to include distances down to 11 m from the nearest visual obstruction as potential roost sites.

An assessment of each of the disturbance variables of the model compared to the results from this study indicated substantial differences. The model suggests a disturbance potential of 400 and 200 m for paved and gravel roads, respectively. However, my results indicate a significant avoidance of areas < 500 and < 400 m from a paved road and gravel road, respectively. Additionally, the model suggests a potential zone of influence associated with a private road to be only 40 m whereas the data from this study suggests a disturbance potential of 100 m. The disturbance potential recommended for a single dwelling by the HSI model was 200 m; however, the results from this study indicate a disturbance potential of 400 m. Furthermore, there is a substantial difference for the disturbance potential created by railroads between the HSI model and this study. The HSI model suggests that the disturbance potential for railroads is 400 m, but I found no use within 600 m of a railroad. Another substantial difference between the HSI model and my observations was the difference in the disturbance potential for highlines. The model states that the disturbance potential for highlines is as low as 40 m, whereas my study indicates a disturbance potential of 200 m for highlines.

CONCLUSIONS

WATER DEPTH. There was no discernible variation in the frequency of water depths used among the four reaches. Frequency distributions among individual sampling dates were computed. In general, use of depths from 1 to 13 cm predominated. There was a small but significant difference in the distribution of depths used between the beginning and end of the study period.

There was a significant difference between the overall distribution of used and available depths. Depths of 1-13 cm were used in greater proportion than those generally available. Exposed sandbars and depths > 20 cm were avoided, while depths of 14-19 cm were generally used in proportion to their availability.

The proportion of depths used by sandhill cranes remained essentially constant over the period of study despite a marked reduction in discharge. A reduction in discharge by as much as 50% changed the availability of water depths but had little or no effect on influencing the overall use of specific water depths.

There were differences between depth criterion for roost sites between this study and the Armbruster and Farmer (1982) HSI model. The model suggests that optimum depths include the range from 10.2 to 20.3 cm. Conversely, the results from this study indicate that optimum depths for roosting include the range from 1 to 13 cm. With this in mind, it is suggested that the Armbruster and Farmer (1981) HSI model be modified to include shallower depths (1-10 cm) as optimum to the exclusion of deeper depths (> 13 cm).

UNOBSTRUCTED AREA. There was a significant difference between the distribution of flock locations and random points relative to the distance from the nearest visual obstruction. Proportional use of sites 11-50 m from the nearest visual obstruction was significantly greater than availability, while sites 0-4 and > 50 m from a visual obstruction were avoided.

Different forms of visual obstructions had differing impacts on the selection of roost sites: vegetated islands had little influence, whereas vegetated and unvegetated banks had greater influence. Sandhill cranes roosted a mean distance of 27 m from vegetated islands and 45 and 50 m from unvegetated and vegetated banks, respectively.

Channels with a minimum unobstructed width of 100-200 m were used in greater proportion than those generally available, while channels narrower than 100 m were avoided. Nearly 100 % of the roosting sandhill crane flocks were located in channels with an unobstructed channel width > 50 m and over 80% were located in channels > 150 m wide. Wide channels potentially provide more space for roosting sandhill cranes, more security from predators, and more available water depths to choose from.

There was a marked difference between this study and the HSI model for the distance to nearest visual obstructions. The model states that cranes required a distance of > 25 m of unobstructed view in all directions before they will use a channel for roosting. In contrast, the results from this study indicate that distances from 11 to 25 m receive the highest frequency of use by cranes.

Therefore, it is suggested that the HSI model be amended to include distances down to 11 m from the nearest visual obstruction as potential roost sites. This study corroborates the channel width criteria proposed by the HSI model. According to the model, optimum conditions for roosting occur when there is a minimum unobstructed channel width > 150 m. The results from this study indicate that sandhill cranes selectively used channels 100-200 m wide and that 80% of the flocks sampled were located in channels with a minimum unobstructed width > 150 m.

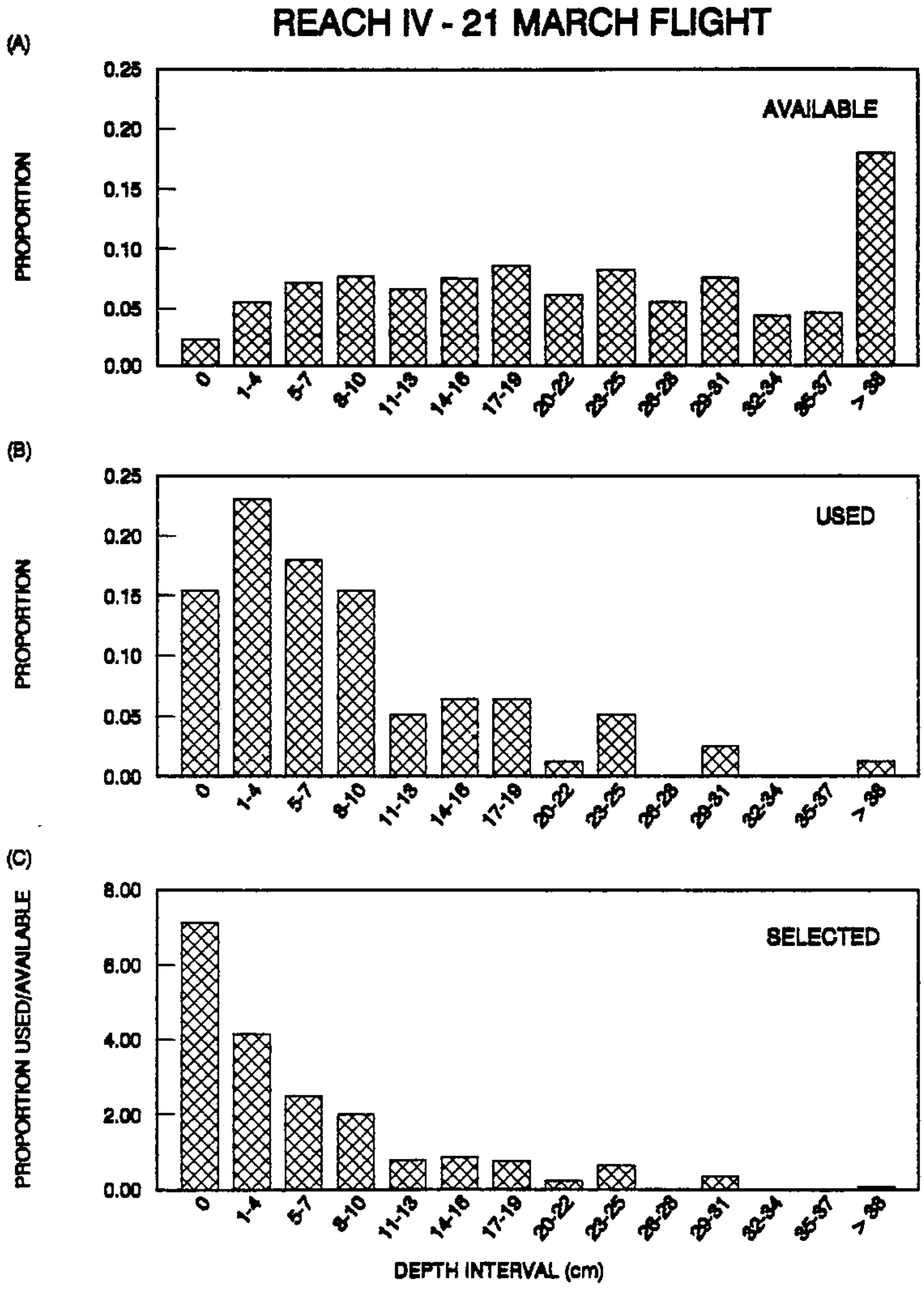
DISTURBANCE FEATURES. Human disturbance features influenced the selection of roost sites. Sandhill crane flocks were distributed randomly with respect to private roads, urban dwellings, gravel pits, commercial development, railroads and highlines. However, flocks were not distributed randomly with respect to paved roads, gravel roads, single dwellings, and bridges.

Sandhill cranes generally avoided areas closer than 500 m of a paved road, 400 m of a gravel road, 400 m of a single dwelling, and 400 m of a bridge. Additionally, the range of disturbance potentially created by private roads was 100 m, urban dwellings 800 m, gravel pits 100 m, commercial development 700 m, railroads 600 m, and highlines 200 m. Furthermore, the presence of a visual obstruction between roosting flocks and paved roads and single dwellings had an effect on their potential zone of influence.

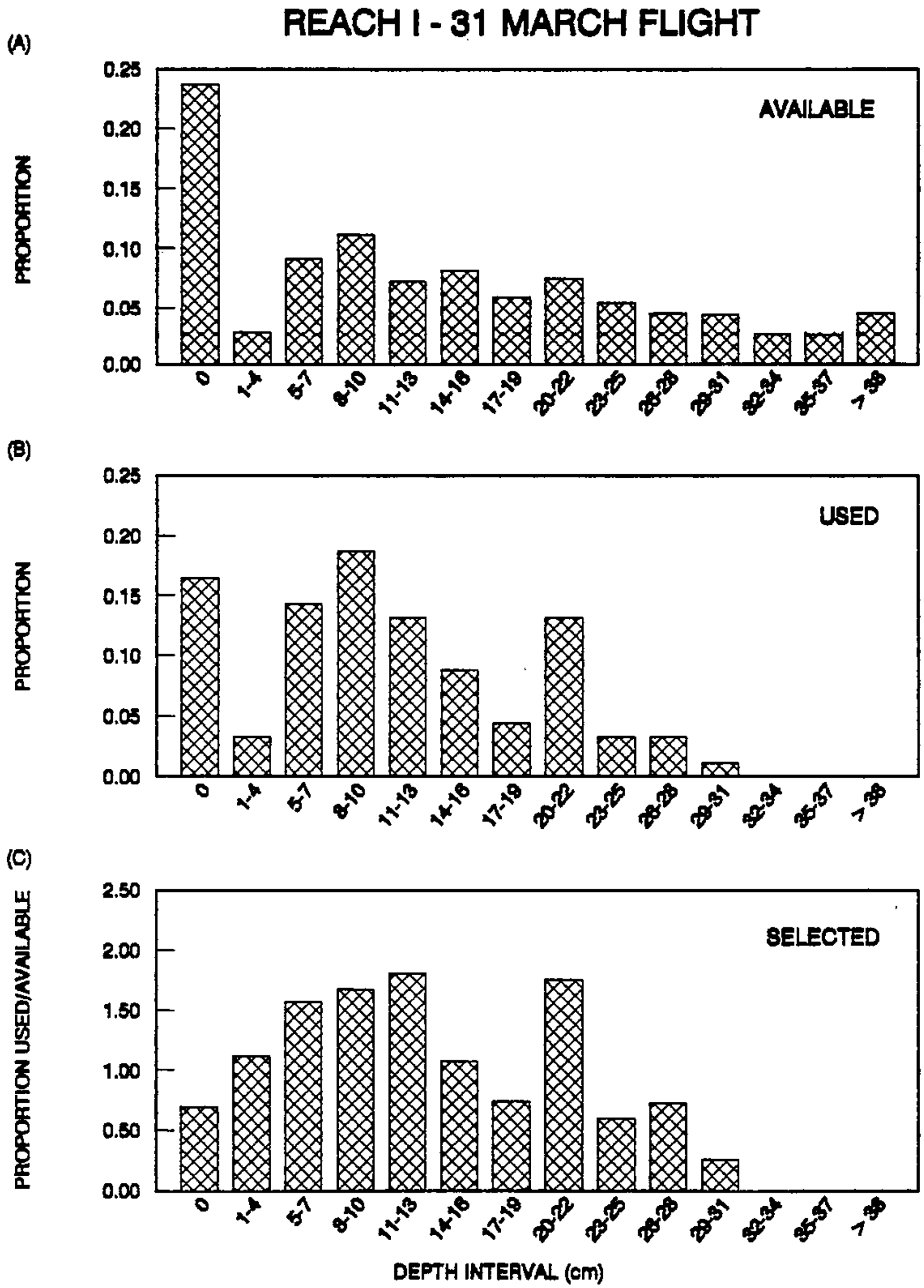
An assessment of each of the disturbance variables of the HSI model compared to the results from this study indicate substantial differences. The model suggests a disturbance potential of 400 and 200 m for paved and gravel roads, respectively. However, my results indicate a significant avoidance of areas < 500 and < 400 m from a paved road and gravel road, respectively. Additionally, the model suggests a potential zone of influence associated with a private road to be only 40 m whereas the data from this study suggests a disturbance potential of 100 m. The disturbance potential recommended for a single dwelling by the HSI model was 200 m; however, the results from this study indicate a disturbance potential of 400 m. Furthermore, there is a substantial difference for the disturbance potential created by railroads between the HSI model and this study. The HSI model suggests that the disturbance potential for railroads is 400 m, but I found no use within 600 m of a railroad. Another substantial difference between the HSI model and my observations was the difference in the disturbance potential for highlines. The model states that the disturbance potential for highlines is as low as 40 m, whereas my study indicates a disturbance potential of 200 m for highlines.

CONSIDERATIONS. It is felt that the results from this study provide a assessment of the influences that water depth, distance to nearest visual obstruction and channel width, as well as disturbance features have on roost site selection by sandhill cranes. However, a problem in assessing the individual influence of these variables is that there is likely to be interactions between variables.

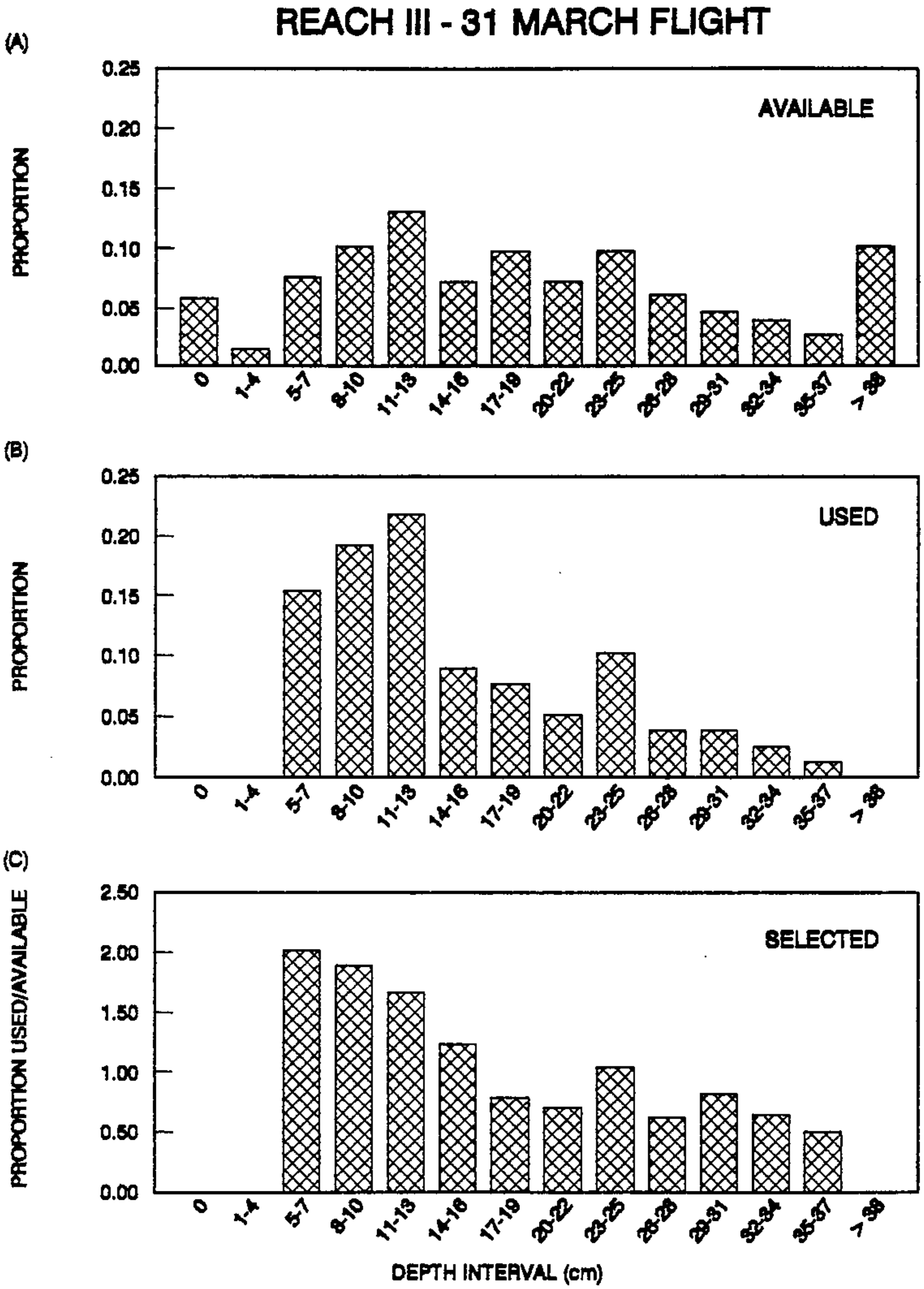
Since depth distribution data were confined to only four independent study sites and data on unobstructed area and disturbance features were confined to a 36-km stretch of the Platte River, my findings may pertain only to those areas. My results indicate that within the study areas, the HSI model was successful at predicting some habitat parameters, while changes were needed for others.



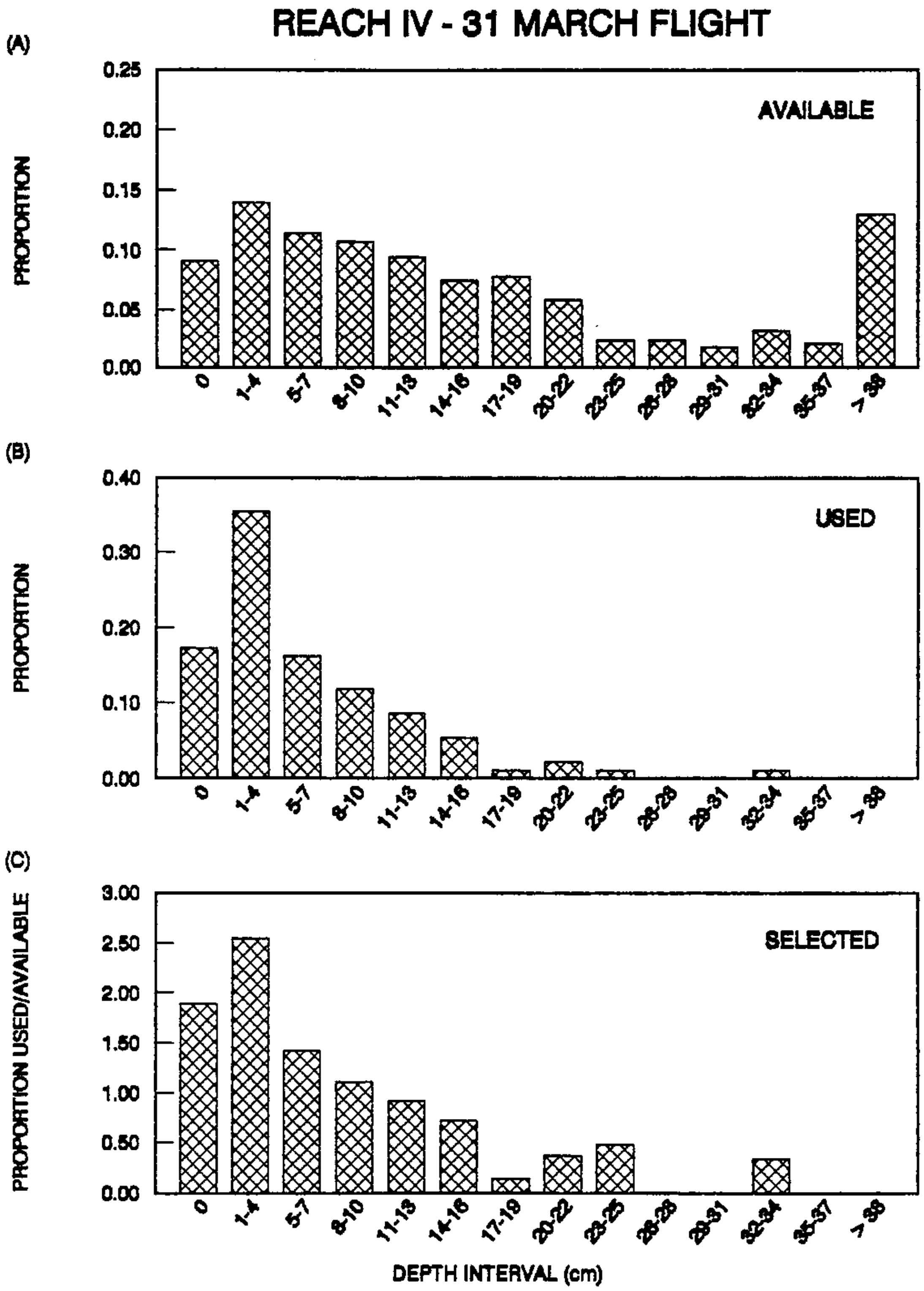
Appendix I. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach IV on 21 March 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach IV on 21 March 1989.



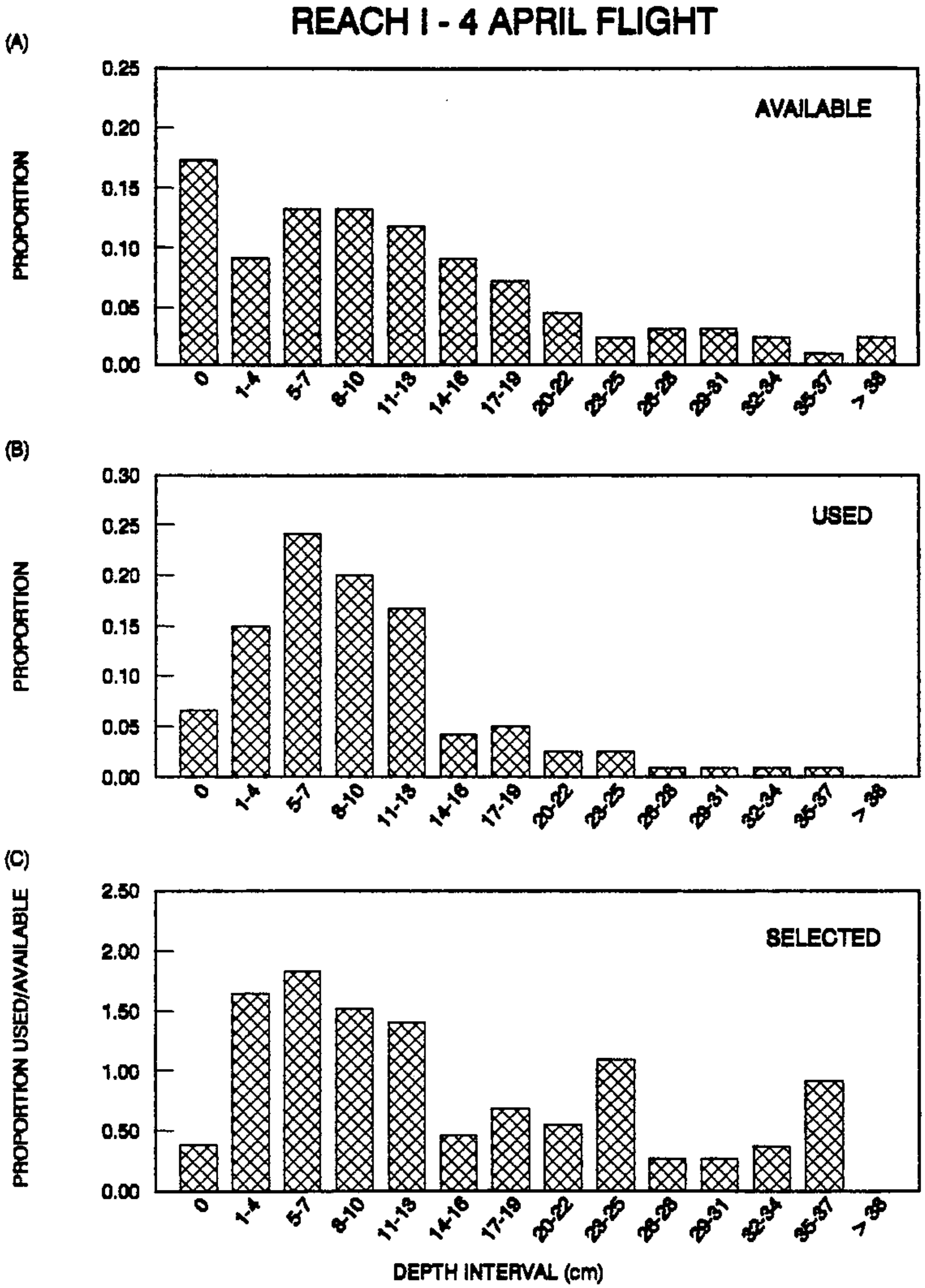
Appendix J. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach I on 31 March 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach I on 31 March 1989.



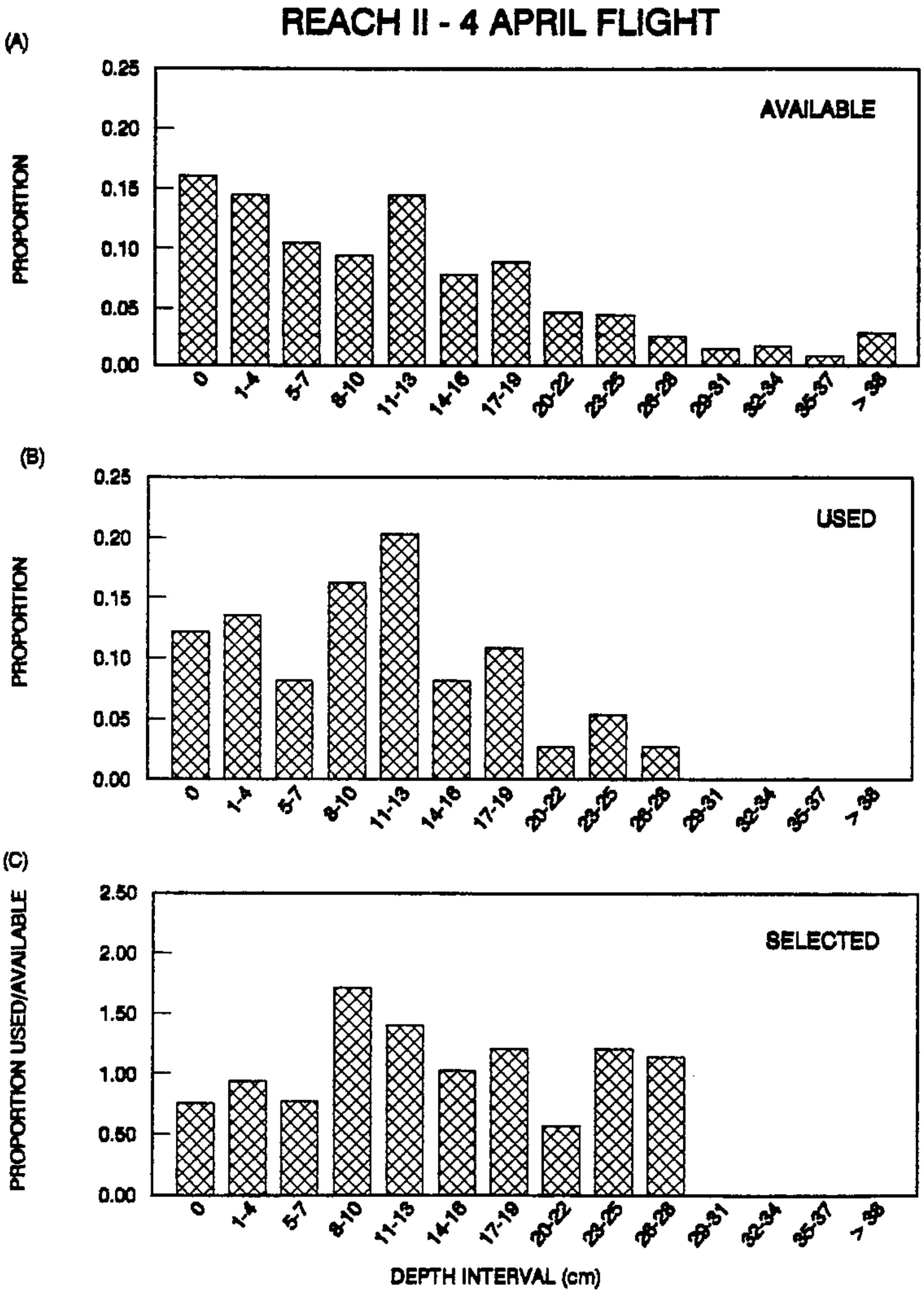
Appendix K. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach III on 31 March 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach III on 31 March 1989.



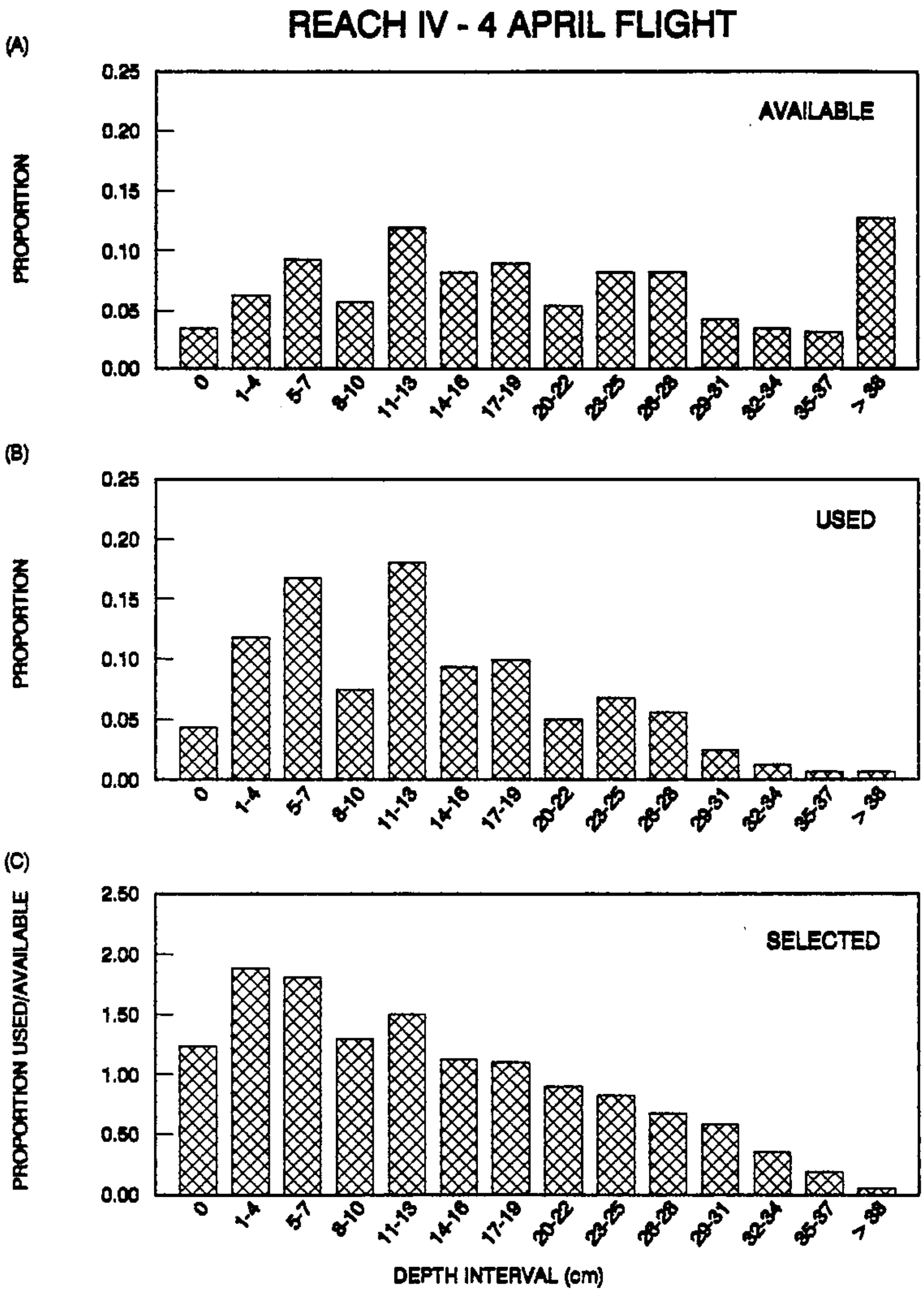
Appendix L. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach IV on 31 March 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach IV on 31 March 1989.



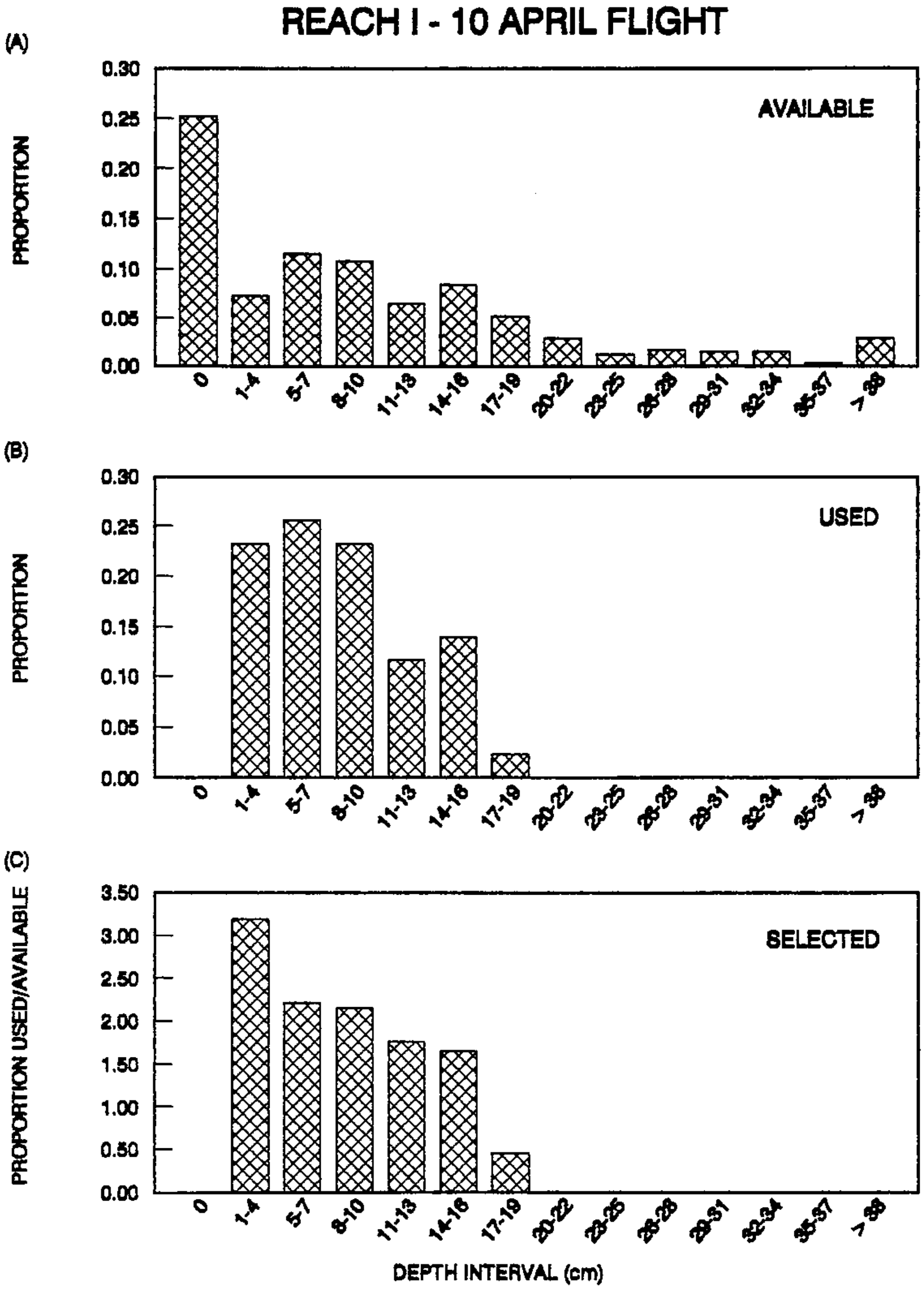
Appendix M. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach I on 4 April 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach I on 4 April 1989.



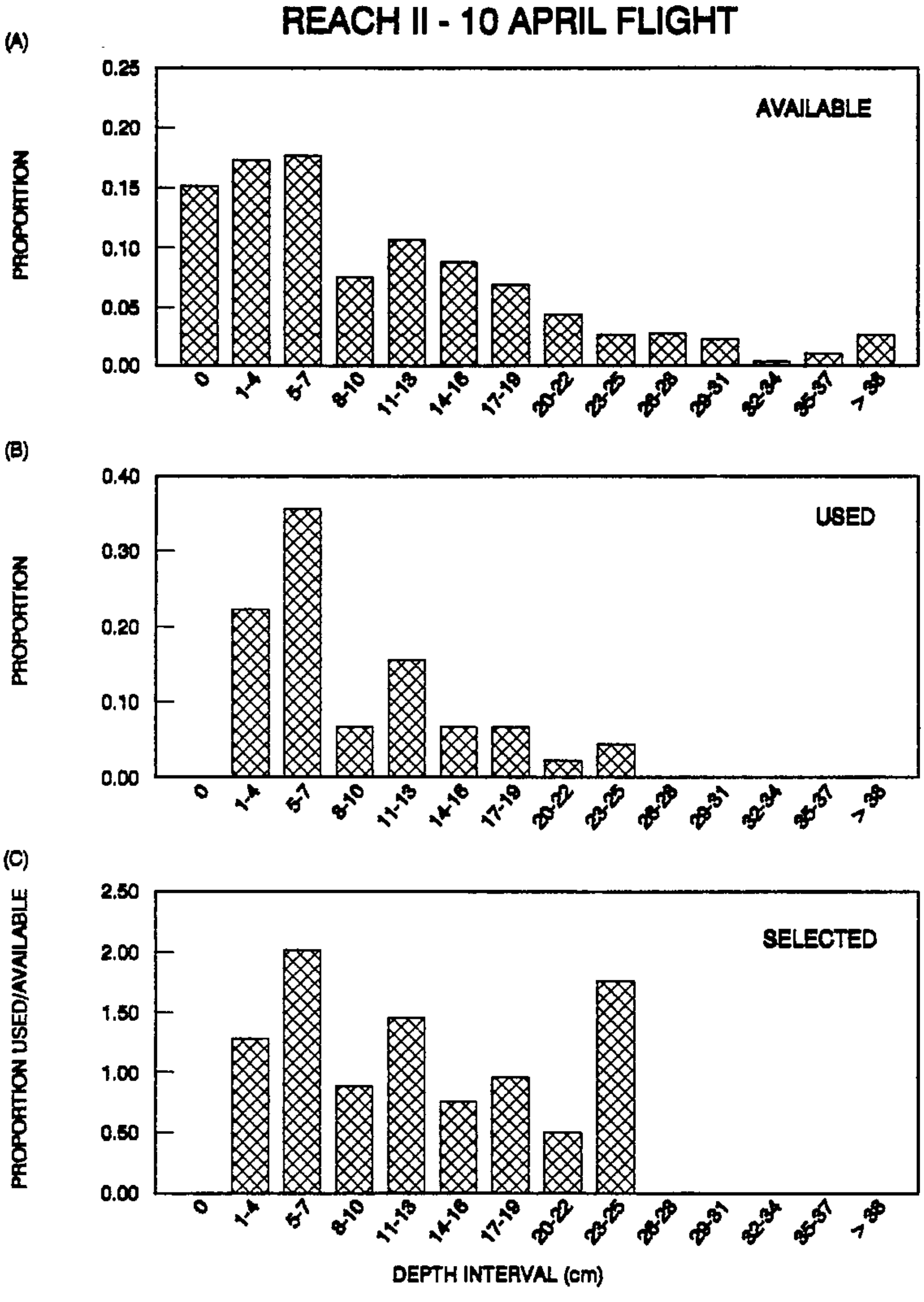
Appendix N. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach II on 4 April 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach II on 4 April 1989.



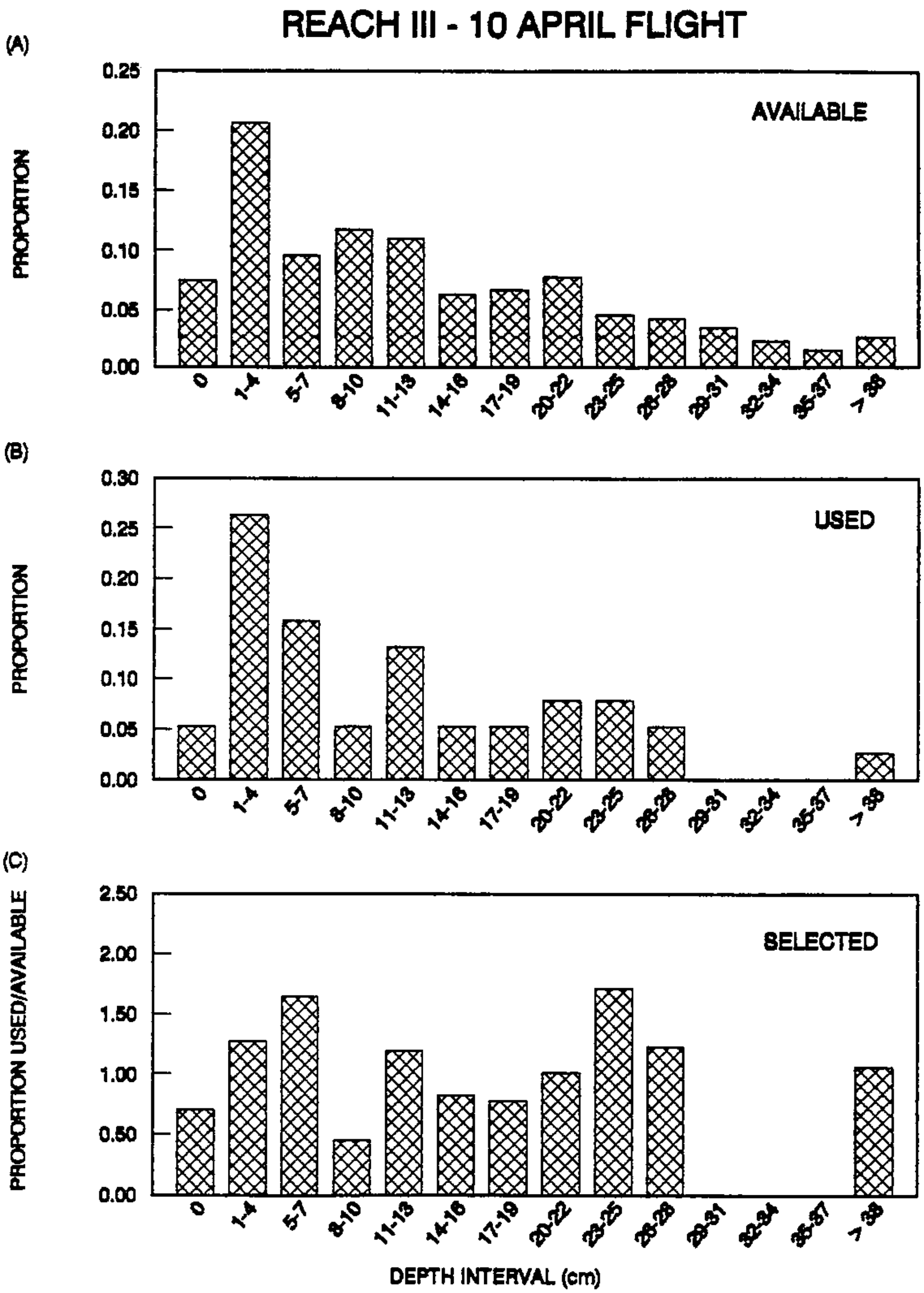
Appendix O. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach IV on 4 April 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach IV on 4 April 1989.



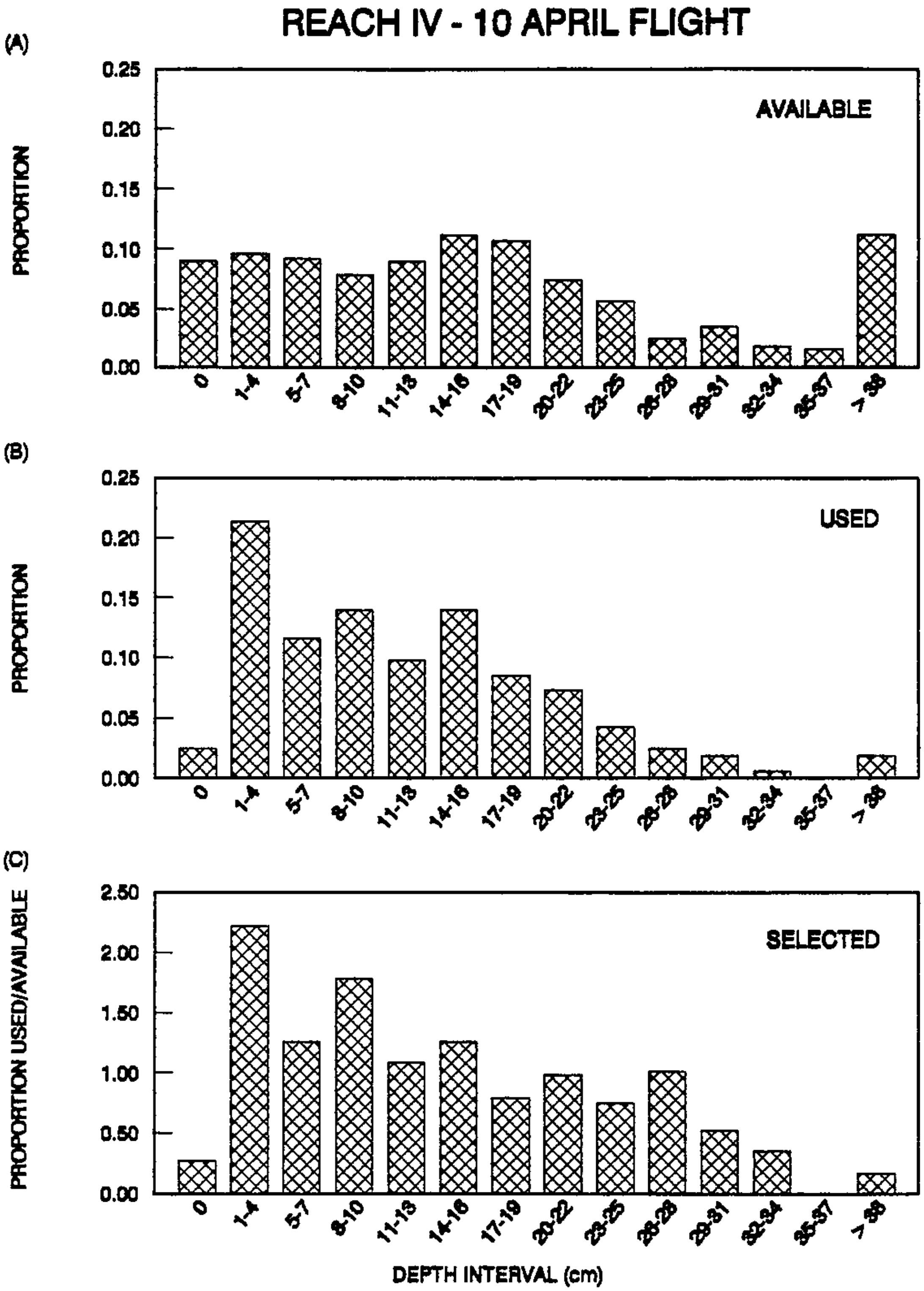
Appendix P. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach I on 10 April 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach I on 10 April 1989.



Appendix Q. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach II on 10 April 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach II on 10 April 1989.



Appendix R. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach III on 10 April 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach III on 10 April 1989.



Appendix S. Frequency Distributions for Available (A), Used (B) and Selected (C) Water Depths in Reach IV on 10 April 1989. The Histograms are Based on Pooled Data from all Flocks Sampled in Reach IV on 10 April 1989.

Appendix T. Differences in the Proportion of Available and Used Water Depths Between the Beginning and End of the Study Period.

Depth (cm)	Available		95% CI on diff. between proportion available	Used		95% CI on diff. between proportion used
	3/21/89	4/10/89		3/21/89	4/10/89	
0	84	217	-0.111 - -0.079*	18	6	0.034 - 0.107*
1 - 4	91	188	-0.085 - -0.055*	36	65	-0.103 - 0.018
5 - 7	108	174	-0.063 - -0.034*	36	52	-0.056 - 0.061
8 - 10	125	139	-0.025 - 0.001	29	38	-0.037 - 0.068
11 - 13	142	134	-0.010 - 0.016	17	33	-0.073 - 0.017
14 - 16	131	133	-0.016 - 0.009	21	34	-0.059 - 0.036
17 - 19	147	112	0.010 - 0.034*	18	20	-0.020 - 0.064
20 - 22	102	82	0.002 - 0.022*	4	16	-0.062 - -0.007*
23 - 25	97	52	0.022 - 0.038*	5	12	-0.043 - 0.010
26 - 28	82	39	0.022 - 0.036*	2	6	-0.029 - 0.007
29 - 31	85	39	0.024 - 0.038*	5	3	-0.006 - 0.036
32 - 34	49	21	0.014 - 0.024*	2	1	-0.006 - 0.020
35 - 37	47	15	0.017 - 0.026*	1	0	-0.003 - 0.013
>38	170	78	0.052 - 0.072*	4	4	-0.014 - 0.026
TOTAL	1460	1423		198	290	

*Failure of 95% CI on differences to overlap 0 indicates a significant difference at $\underline{P} \leq 0.05$.

Appendix U. Differences Between the Proportion of Used and Available Water Depths for the Sampling Period of 21 March and 31 March, 1989.

	3/21/89 FLIGHT			3/31/89 FLIGHT		
Depth (cm)	Used	Avail.	95% CI on diff. between prop. used & available	Used	Avail.	95% CI on diff. between prop. used & available
0	18	84	-0.002 - 0.068	31	148	-0.064 - 0.011
1 - 4	36	91	0.073 - 0.166^{b}	36	60	0.042 - 0.116^{b}
5 - 7	36	108	0.061 - 0.154^{b}	40	96	0.019 - 0.098^{b}
8 - 10	29	125	0.018 - 0.104^{b}	43	110	0.016 - 0.097^{b}
11 - 13	17	142	-0.047 - 0.024	37	97	0.008 - 0.085^{b}
14 - 16	21	131	-0.022 - 0.054	20	79	-0.031 - 0.029
17 - 19	18	147	-0.046 - 0.026	11	77	-0.058 - -0.009^{a}
20 - 22	4	102	-0.069 - -0.030^{a}	18	71	-0.030 - 0.028
23 - 25	5	97	-0.062 - -0.020^{a}	12	58	-0.035 - 0.013
26 - 28	2	82	-0.061 - -0.031^{a}	6	44	-0.039 - -0.002^{a}
29 - 31	5	85	-0.054 - -0.012^{a}	4	37	-0.037 - -0.005^{a}
32 - 34	2	49	-0.037 - -0.009^{a}	3	32	-0.034 - -0.006^{a}
35 - 37	1	47	-0.038 - -0.016^{a}	1	25	-0.031 - -0.011^{a}
>38	4	170	-0.118 - -0.075^{a}	0	88	-0.101 - -0.072^{a}
TOTAL	198	1460		262	1022	

[a] Indicates use less than expected by chance.
[b] Indicates use more than expected by chance.

Appendix U. (Continued)

	4/04/89 FLIGHT			4/10/89 FLIGHT		
Depth (cm)	Used	Avail.	95% CI on diff. between prop. used & available	Used	Avail.	95% CI on diff. between prop. used & available
0	24	163	-0.095 - -0.041[a]	6	217	-0.153 - -0.111[a]
1 - 4	47	121	-0.001 - 0.065	65	188	0.049 - 0.135[b]
5 - 7	62	128	0.032 - 0.105[b]	52	174	0.017 - 0.097[b]
8 - 10	48	114	0.008 - 0.073[b]	38	139	-0.002 - 0.068
11 - 13	64	148	0.020 - 0.094[b]	33	134	-0.014 - 0.053
14 - 16	26	91	-0.028 - 0.024	34	133	-0.010 - 0.057
17 - 19	30	103	-0.029 - 0.027	20	112	-0.037 - 0.017
20 - 22	13	63	-0.035 - 0.004	16	82	-0.027 - 0.022
23 - 25	18	66	-0.026 - 0.018	12	52	-0.016 - 0.026
26 - 28	12	55	-0.031 - 0.007	6	39	-0.022 - 0.009
29 - 31	5	32	-0.025 - 0.000[a]	3	39	-0.029 - -0.005[a]
32 - 34	3	31	-0.028 - -0.006[a]	1	21	-0.019 - -0.004[a]
35 - 37	2	20	-0.020 - -0.002[a]	0	15	-0.015 - -0.006[a]
>38	1	69	-0.066 - -0.043[a]	4	78	-0.056 - -0.026[a]
TOTAL	355	1204		290	1423	

[a] Indicates use less than expected by chance.
[b] Indicates use more than expected by chance.

Appendix V. Differences Between the Proportion of Used and Available Water Depths for Pooled Data Across all Reaches and Flight Dates.

Depth (cm)	Used	Available	95% CI on the difference between proportion used and available
0	79	612	-0.065 - -0.031[a]
1 - 4	184	460	0.060 - 0.093[b]
5 - 7	190	506	0.056 - 0.090[b]
8 - 10	158	488	0.031 - 0.064[b]
11 - 13	151	521	0.018 - 0.052[b]
14 - 16	101	434	-0.009 - 0.022
17 - 19	79	439	-0.030 - 0.001
20 - 22	51	318	-0.029 - -0.003[a]
23 - 25	47	273	-0.023 - 0.001
26 - 28	26	220	-0.030 - -0.009[a]
29 - 31	17	193	-0.032 - -0.013[a]
32 - 34	9	133	-0.026 - -0.010[a]
35 - 37	4	107	-0.025 - -0.010[a]
>38	9	405	-0.085 - -0.058[a]
TOTAL	1105	5109	

[a] Indicates use less than expected by chance.
[b] Indicates use more than expected by chance.

Appendix W. Differences Between the Proportion of Sites Used and Available Relative to the Distance from the Nearest Visual Obstruction.

Distance (m)	Used	Random	95% CI on the difference between proportion used and available
0 - 25	139	130	0.039 - 0.170[b]
26 - 50	76	66	0.016 - 0.128[b]
51 - 75	37	61	-0.098 - -0.003[a]
76 - 100	15	42	-0.108 - -0.035[a]
101 - 125	17	23	-0.040 - 0.024
126 - 150	1	9	-0.039 - -0.008[a]
151 - 175	0	3	-0.017 - 0.000
176 - 200	0	5	-0.026 - -0.004[a]
TOTAL	285	339	

Distance (m)	Used	Random	95% CI on the difference between proportion used and available
0	0	47	-0.428 - -0.290[a]
1 - 4	0	11	-0.124 - -0.044[a]
5 - 10	27	21	-0.042 - 0.110
11 - 15	38	19	0.048 - 0.209[b]
16 - 20	35	12	0.087 - 0.234[b]
21 - 25	39	21	0.038 - 0.202[b]
TOTAL	139	131	

[a] Indicates avoidance.
[b] Indicates use more than expected by chance.

Appendix X. Difference Between the Proportion of Sites Used and Available Relative to the Minimum Unobstructed Channel Width.

Channel width (m)	Used	Random	95% CI on the difference between proportion used and available
0- 50	0	1	-0.008 - 0.002
51- 100	8	23	-0.067 - -0.012[a]
101- 150	50	35	0.026 - 0.118[b]
151- 200	32	24	0.003 - 0.080[b]
201- 250	43	45	-0.028 - 0.064
251- 300	64	83	-0.076 - 0.036
301- 350	62	73	-0.052 - 0.057
351- 400	17	31	-0.066 - 0.003
401- 450	8	14	-0.037 - 0.011
>450	1	11	-0.046 - -0.012[a]
TOTAL	285	339	

[a] Indicates avoidance.
[b] Indicates use more than expected by chance.

Appendix Y. Differences Between the Proportion of Sites Used and Available Relative to the Distance from Paved and Gravel Roads.

	PAVED ROADS			GRAVEL ROADS		
Distance (m)	Used	Random	95% CI on diff. between prop. used & available	Used	Random	95% CI on diff. between prop. used & available
0 - 100	0	5	-0.026 - -0.004[a]	0	0	0.000 - 0.000
101 - 200	0	10	-0.045 - -0.014[a]	0	5	-0.026 - -0.004[a]
201 - 300	0	13	-0.056 - -0.021[a]	0	10	-0.045 - -0.014[a]
301 - 400	1	21	-0.080 - -0.036[a]	6	18	-0.056 - -0.008[a]
401 - 500	2	16	-0.061 - -0.020[a]	18	25	-0.044 - 0.023
501 - 600	10	17	-0.042 - 0.011	28	28	-0.022 - 0.054
601 - 700	15	22	-0.043 - 0.019	46	35	0.013 - 0.103[b]
701 - 800	38	15	0.051 - 0.127[b]	52	35	0.033 - 0.126[b]
801 - 900	27	18	0.007 - 0.077[b]	22	25	-0.032 - 0.038
901 - 1000	24	26	-0.029 - 0.044	21	23	-0.028 - 0.040
1001 - 1100	11	8	-0.008 - 0.038	13	15	-0.026 - 0.029
1101 - 1200	11	10	-0.015 - 0.033	8	12	-0.030 - 0.016
1201 - 1300	8	15	-0.041 - 0.008	12	14	-0.026 - 0.027
1301 - 1400	1	11	-0.046 - -0.012[a]	6	8	-0.022 - 0.017
1401 - 1500	4	10	-0.034 - 0.004	7	6	-0.012 - 0.026
1501 - 1600	21	15	-0.002 - 0.061	4	7	-0.024 - 0.010
>1600	112	107	0.014 - 0.141	42	73	-0.118 - -0.018[a]
TOTAL	285	339		285	339	

[a] Indicates avoidance.
[b] Indicates use more than expected by chance.

Appendix Z. Differences Between the Proportion of Sites Used and Available Relative to the Distance from Single Dwellings and Bridges.

	SINGLE DWELLING			BRIDGES		
Distance (m)	Used	Random	95% CI on diff. between prop. used & available	Used	Random	95% CI on diff. between prop. used & available
0 - 100	0	2	-0.013 - 0.001	0	5	-0.026 - -0.004[a]
101 - 200	2	6	-0.025 - 0.004	0	8	-0.037 - -0.010[a]
201 - 300	0	13	-0.056 - -0.021[a]	0	6	-0.029 - -0.006[a]
301 - 400	7	23	-0.070 - -0.016[a]	0	7	-0.033 - -0.008[a]
401 - 500	20	23	-0.031 - 0.036	3	9	-0.033 - 0.001
501 - 600	37	27	0.009 - 0.091[b]	2	11	-0.043 - -0.008[a]
601 - 700	35	34	-0.019 - 0.064	4	8	-0.027 - 0.008
701 - 800	36	30	-0.003 - 0.079	7	3	-0.002 - 0.033
801 - 900	25	29	-0.035 - 0.039	3	5	-0.019 - 0.010
901 - 1000	30	34	-0.035 - 0.045	5	2	-0.003 - 0.026
1001 - 1100	28	32	-0.035 - 0.043	1	6	-0.027 - -0.001[a]
1101 - 1200	15	23	-0.046 - 0.016	4	4	-0.013 - 0.017
1201 - 1300	28	28	-0.022 - 0.054	4	7	-0.024 - 0.010
1301 - 1400	12	11	-0.016 - 0.035	1	7	-0.031 - -0.003[a]
1401 - 1500	3	15	-0.055 - -0.013[a]	2	9	-0.036 - -0.003[a]
1501 - 1600	3	6	-0.023 - 0.008	0	6	-0.029 - -0.006[a]
>1600	4	3	-0.009 - 0.019	246	236	0.125 - 0.230[b]
TOTAL	285	339		285	339	

[a] Indicates avoidance.
[b] Indicates use more than expected by chance.

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