PROCEEDINGS 1981 CRANE WORKSHOP

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PREFACE

This Proceedings includes 29 of the 30 papers presented at the 1981 Crane Workshop held 25-27 August in Grand Tetons National Park, Wyoming. Published here, along with the 29 papers mentioned previously are 10 papers submitted for the Proceedings but not presented at the Workshop. These latter papers were not presented at the Workshop because the authors were unable to attend the meeting due to limited finances or time conflicts.

The 1981 Workshop was the 3rd in a series of such workshops held in the United States; the previous meetings were in Baraboo, Wisconsin, in 1975 and Rockport, Texas, in 1978. The National Audubon Society sponsored this Proceedings and that of the 1978 Crane Workshop and I thank Eugene Knoder for making this publication possible and for helping our programs in many other ways. The Oklahoma Cooperative Wildlife Research Unit sponsored publication of the 1975 meeting. The first crane workshop was organized in response to the need for management and research information on cranes. This need was evidenced by gaps in our knowledge of the ecology of the endangered whooping crane, by increasing complaints of crop depredations by sandhill cranes, and by increased hunter harvest of sandhill cranes at a time when we lacked some data desirable for proper management. The series of workshops and proceedings have been designed to improve communication and interaction among those researching or managing cranes in North America, to stimulate further research, to help identify research and management needs, and to provide ease of access to a large amount of crane literature. A few copies of the Proceedings of the International Crane Workshop (published in 1976, 40 articles, 351 pages) are still available from the Oklahoma Cooperative Wildlife Research Unit, 404 LSW, Oklahoma State University, Stillwater, OK 74078 for $6.00. Proceedings of the 1978 Crane Workshop (published in 1979, 36 articles, 259 pages) are available from Eugene Knoder, National Audubon Society, 645 Pennsylvania Ave SE, Washington, D.C. 20003 for $6.00.

Other recent publications of interest to crane researchers and managers are the Platte River Ecology Study: Special Research Report (published 1981, 186 pp.) available free from U.S. Fish and Wildlife Service, Northern Prairie Research Center, P. O. Box 1747, Jamestown, North Dakota 58401; Crane Research Around the World (published 1981, 48 articles, 260 pages, 55 photos) is available from International Crane Foundation, City View Road, Baraboo, Wisconsin 53913 for $15.00; the Niobrara River Whooping Crane Habitat Study (356 pages) is available by writing Regional Environmental Specialist, Bureu of Reclamation, Lower Missouri Region Office, Denver Federal Center, P.O Box 25247, Denver, Colorado 80225.

The sandhill crane shown on the Proceedings cover was photographed at Washita National Wildlife Refuge, Oklahoma, by an employee of the U.S. Fish and Wildlife Service. I thank the U.S. Fish and Wildlife Service for use of the photo, for providing the paper stock used for camera-ready copy, and for contributing some of my work time.--J. C. Lewis

W.J.D. STEPHEN, 1930-1981

Crane biologists recently lost 1 of their most active Canadian colleagues. On 14 January 1981, during Canadian Wildlife Service (CWS) Program Reviews in Edmonton, William John Douglas Stephen died suddenly. Although Doug had not been feeling well for a few days, there appeared to have been no advance warning of the severe heart attack which felled him in mid-career.

Doug was born in 1930 in Sudbury, Ontario, earning his BSA in 1957 at the University of Toronto's Ontario Agricultural College in Guelph. Three years later, also at OAC, he received his MSA. He joined CWS in July 1959 in Saskatoon where he studied the effects of waterfowl depredations on cereal crops in the prairies. From 1961 to 1963 Doug studied sandhill cranes, and this study led to his Ph.D. degree from the University of Saskatchewan in 1965. Doug experimented with methods for controlling waterfowl depredations on grain and he investigated the effectiveness of experimental lure crops. The work resulted in contributions to the North American Wildlife Conference and to several journals; some of his findings are still being applied.

In September 1966, Doug was transferred to Edmonton to become Supervisor of Lands with CWS. His new duties included the management of lands leased for waterfowl production and development of management plans on federal land. Three years later he took a 1-year position in Ottawa with the Science Council of Canada, returning afterwards to Edmonton to become Manager, Migratory Birds Division, Western Region. In 1974 he became Director, Western Region. In the mid-1970's Doug was the Canadian representative on the Sandhill Crane Subcommittee which summarized what was then known about the species and identified research and management needs. In 1976 Doug returned to active field research conducted from the Saskatoon office. There he studied sandhill cranes to identify a suitable population that might serve as foster-parents for whooping cranes as had occurred in the Grays Lake, Idaho, program. Doug was also developing methods for identification of sandhill crane breeding habitat using satellite imagery. In 1977 he assisted with the tricky job of banding the 1st young whooping cranes caught in Canada. As a research scientist he was greatly respected by his colleagues. He will be greatly missed by his many friends.

Ernie Kuyt and Colleagues,
Canadian Wildlife Service

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1981 CRANE WORKSHOP: A SYNOPSIS

GEORGE W. ARCHIBALD, Co-founder, International Crane Foundation, Baraboo, WI 53913

At 2,100 m above sea level, beside a lake that reflects the magnificence of the Grand Tetons and on which trumpeter swans (*Olor buccinator*) float, crane researchers from Canada, Japan, and the USA, gathered for 3 days to discuss happenings in the world of North America's Gruidae since our last gathering at Rockport, Texas, in December of 1978. We roosted at Colter Bay campground, "crainestormed" (sic) at the University of Wyoming National Park Research Center, and migrated for a day to Grays Lake National Wildlife Refuge to appreciate whooping (*Grus americana*) and sandhill cranes (*G. canadensis*). Our western comrades Jim Lewis and Rod Drewien organized the meeting and their warmth and enthusiasm, coupled with the splendors of northwest Wyoming, made it a pleasant meeting for crane people from Hokkaido to Maryland.

The meeting concentrated on sandhill, whoopers, and captive management, except for a spectacular slide show by photographer-conservationist Tsuneo Hayashida on the red-crowned cranes (*G. japonensis*) of northern Japan and a paper by George Archibald regarding a possible cross-fostering of the acutely threatened Siberian crane (*G. leucogeranus*) by lesser sandhills (*G. c. canadensis*) in eastern Siberia.

Extensive research was eloquently presented by Gary Krapu and his team from the Northern Prairie Wildlife Research Center, U.S. Fish and Wildlife Service, and Tom Tacha et al. of the Oklahoma Cooperative Wildlife Research Unit as they elucidated man's understanding of 1 of earth's greatest and most threatened wildlife spectacles--the spring staging of some 400,000 lesser, Canadian (*G. c. rowani*), and greater sandhills (*G. c. tabida*) along 365 km of the Platte River, Nebraska. During the cranes' several weeks stay in Nebraska, they predominantly feed in cornfields and increase their fat deposits for the long trip north to the breeding grounds. At night they roost on sandbars in the river. But unfortunately, since white settlement, the flow of the Platte has decreased by 70% in some river sections, in response to damming of upstream tributaries and water diversion for irrigation. If the sandbars continue to be covered by fast-growing woody vegetation as a consequence of reduced water levels, the cranes may be forced to roost in wetlands of the nearby Rainwater Basin, wetlands that are infested with avian cholera that has claimed the lives of tens of thousands of ducks and geese in recent spring seasons.

In response to the Platte River crisis, the Whooping Crane Habitat Maintenance Trust was established to resolve a problem that not only threatens a majority of the sandhill cranes that nest in Canada, Alaska, and the USSR, but also concerns the whooping cranes of the Wood Buffalo National Park flock that migrate through Nebraska each spring. Under the skilled direction of Trust Administrator, John VanDerwalker, critical riparian habitats are being purchased and managed to benefit cranes. For example, profits from Trust-owned alfalfa and corn crops near the river are used to bulldoze down trees and brush that cover former crane roosts in the river. A computer model is being developed to document crane use and habitat changes along a 145-km stretch of the Platte and extending 8 km on each side of the river, a program from which priorities of conservation action can be identified in maintaining a proper balance of cropland, riparian meadow, and roost habitats.

The Platte studies, and parallel research by Jim Lovvorn on the eastern flock of greater sandhills that nest in the Lake States, reinforce the axiom that population size is related to food and protection. All migratory subspecies of sandhill crane are increasing by the thousands, undoubtedly because they benefit from abundant gleanings in agricultural fields during migration and on their wintering grounds. In presettlement times these migratory sandhills very likely fed predominantly on seeds and sedge tubers laboriously secured in natural prairie and marshland habitats. Milo in Texas, and corn in Nebraska, have perhaps eliminated food as a limiting factor to sandhill crane populations and, thus, the population increases despite the loss of 16,000 birds annually to hunters in Alaska and along the Central Flyway.

Crane migration has been the focus of several studies including the historic radio-tracking of sandhills migrating from Wisconsin to Florida (reported by Ron Crete and John Toepler in the 1978 Proceedings) and of the Interlake crane population of Manitoba in their passage to the Gulf Coast of Texas (by Scott Melvin, S. A. Temple, and Douglas Stephan) as described by Scott this year. The Interlake sandhills migrated during daylight at 19 to 50 km per hour and covered from 48 to 740 km before stopping to roost at whatever shallow wetlands were along their route.

The telemetry researchers followed the greater sandhill by air and ground, while Dale Herter and Pam Soine examined the general ecology and roost site selection of subspecies as they passed through the Copper River Delta of southeastern Alaska and the fertile plains of southwest North Dakota, respectively. Of the 25,000 lesser sandhills that Littlefield and Thompson reported wintering in areas of California, most of the birds are expected to fly through southeast Alaska based on the observation of 5 California-marked cranes on the Copper Delta. Lesser sandhills in Alaska forage on sedge tubers and other wild plants but cranes passing through North Dakota benefit from wheat while staging in enormous flocks. Pam Soine developed an excellent methodology for recording criterion of various shallow wetlands in North Dakota to determine why sandhills chose to roost in some areas and not in others. Water depth, visibility, and proximity to food were pertinent factors Pam introduced a new measurement of water called "crane depth." A modeled crane foot, attached to a dowel weighted equivalent to the weight of a sandhill, was used to measure how far a crane's foot sinks in the mud substrate and rests beneath the water surface--an important consideration for a roosting crane.

Although most reports concerned the migratory sandhills, Jacob Valentine, who retired in September 1981 after many years of excellent service with the USFWS in Mississippi, brought news regarding America's most endangered subspecies, the Mississippi sandhills (*G. c. pulla*). When John Aldrich described the race in 1972, there were about 50 cranes left on the pine savannahs of Jackson County, Mississippi, and their remnant breeding habitat was threatened by the construction of an interstate highway. A supreme court decision in 1976 declared the construction was destroying critical habitat. The Nature Conservancy and the U.S. Government then bought and protected additional wetlands giving the crane a refuge of 6,480 ha that are now being managed to increase the crane population. The population has dropped to 30; however, with cropland planted just for the cranes, old drainage channels blocked, and more dams constructed to produce nesting wetlands, the little flock is expected to increase. In fact, in 1981, 9 more cranes were added to the flock from cranes raised at the Patuxent Wildlife Research Center.

Scott Derrickson of Patuxent Wildlife Research Center, Laurel, Maryland, enthused workshop participants with his description of the challenging tasks, 1st of inducing Mississippi sandhills and whoopers at Patuxent to breed in captivity, and then of releasing captivity-reared birds into the wild. Hand-reared cranes become tame and must always be kept in captivity, whereas chicks reared by cranes are wild. Rod Drewien and Soctt Derrickson described 2 experiments developed to test techniques for releasing crane-reared captive cranes back into the wild. Initially they selected 12 greater sandhills pen-reared at Patuxent and released them, without an opportunity to adjust gradually, with the wild greater sandhills at Grays Lake National Wildlife Refuge in Idaho. Drewien and Derrickson found that yearling birds adapt best to the wild because of their tendency to form stronger bonds with the wild cranes than did the 2- and 3-year-old birds. Problems encountered at Grays Lake were avoided in a "gentle release" of pen-reared Mississippi sandhills on the refuge in Jackson County, Mississippi. The sandhills were wing-brailed and released into a spacious confine within the habitats of the wild cranes. The brails were removed after the sandhills acclimated to their new surroundings. The 9 birds reared at Patuxent have all successfully adapted to the wild, thus increasing the free population of this endangered subspecies by 23%.

The highlight of endangerment is the whooping crane. Unfortunately, Canadian Wildlife Service Whooper expert, Ernie Kuyt, was fighting forest fires in Wood Buffalo National Park and was unable to attend the workshop. However, David Blankinship of the National Audubon Society, who follows the winter life of the rare white cranes at the other end of their 4,830-km migration route, provided an up-to-date report. Since 1977, prefledged whoopers have been captured and color-marked in Wood Buffalo National Park. Of 29 birds marked between 1979 and 1980, 25 survived their 1st migration and 24 their 1st winter. Of 22 pairs breeding in Canada at the peak in 1980, 15 different pairs have brought young to Aransas. Dave and Ernie conjecture that 22 to 25 pairs of whoopers should be breeding if the drought, which has continued in subarctic Canada for 3 years, stops in 1982. Mary Bishop, also with the National Audubon Society, has been observing the marked subadult cranes at the Aransas National Wildlife Refuge and has noticed that flock size decreases in late winter, presumably as subadults pair and disperse. In fact, whoopers may breed at a much younger age than formerly believed. Two pairs at Wood Buffalo in 1980 had members that were 3 years old.

The traditional whooping crane flock continued its slow increase and researchers conclude that the greatest mortality does not occur in subadult cranes but in paired birds, data that concurs with Scott Derrickson's data from Patuxent where adult whoopers have a 3-fold higher mortality than immatures.

International interest has focused on the cross foster experiment in Idaho where, under the leadership of Elwood Bizeau and Rod Drewien, a new flock of whoopers has been developed by substituting whooper eggs into the nest of the ubiquitous greater sandhills. Elwood and Rod provided a tour of the set of this wildlife drama, Grays Lake National Wildlife Refuge, and updated our facts. Unfortunately embryonic deaths and poor water conditions at Grays Lake claimed the lives of all whooper chicks in 1981. However, 15 birds raised in other years were accounted for, and 1 territorial male was provided a pen-reared female from Patuxent. Despite use of the gentle release technique, a strong pair bond did not develop. However, the male indicated a positive response to the female by doubling the size of his territory, much to the consternation of neighboring pairs of sandhills.

By aircraft in 1980 Rod had followed a radio-marked whooper from Grays Lake to Monte Vista National Wildlife Refuge in Colorado. The bird flew 265 km the 1st day and climbed to an altitude of 4,025 m. Jon Kaufield reported that cranes spent more time at Monte Vista than at either their breeding ground (Grays Lake) or wintering turf (Bosque del Apache National Wildlife Refuge). Unfortunately 3 whoopers died at Monte Vista through collision with fences and wires and this problem is not expected to abate.

As usual, Florida's crane researcher, Steve Nesbitt, had an innovative idea to elucidate. Why not initiate a nonmigratory whooper flock in south central Florida where a political and biological climate prevails to welcome and provide for the cranes? Eggs produced at Patuxent in early spring, that cannot be substituted into greater sandhill nests in Idaho because the cranes there are not yet nesting, could be substituted into Florida sandhill (*G. c. pratensis*) nests in March and April within a 20,250-ha wetland reserve where the subspecies flourishes. Steve has embarked on a 5-year intensive study of greater and Florida sandhills to determine if the former will become nonmigratory when reared by the latter, data that will better pave the way for efforts to establish sedentary whoopers.

The potential of captive breeding was evidenced by release of the Patuxent-produced Mississippi sandhill cranes and the issuance of whooping crane eggs from Patuxent to greater sandhill nests in Idaho where 3 whoopers are now in the wild as a consequence of captive production. Scott Derrickson outlined the mortality agents among captive whoopers while Mike Putnam indicated the overall status of captive management at the International Crane Foundation (ICF) where efforts are being made to propagate all endangered species of cranes. ICF researcher Shirley Russman outlined our knowledge of sperm morphology, while John Riley indicated that temperatures of naturally incubated eggs vary greatly and that perhaps such a regimen might improve the strength of artifically incubated embryos. Mike outlined a new and somewhat radical cooling technique for the eggs of cold-climate species. ICF hatchability improved markedly in 1981, perhaps as a result of the cooling and also perhaps because of a new incubator.

We were sad to leave our colleagues and the Grand Tetons but were comforted by a suggestion that we stage with the sandhills in Nebraska in March of 1984. Until then, crane research is flying.

THE PLATTE RIVER WHOOPING CRANE CRITICAL HABITAT MAINTENANCE TRUST

JOHN G. VanDERWALKER, The Platte River Trust, 2550 N Diers Avenue, Suite H, Grand Island, NE 68801

Abstract: In 1975, Basin Electric Power Cooperative applied for a Section 404 permit to build Grayrocks Dam. The state of Nebraska and the National Wildlife Federation (NWF) objected, claiming the diversion and consumption of 23,250 acre-feet of water would damage wildlife habitat in Nebraska and further threaten the whooping crane (*Grus americana*) habitat on the Big Bend of the Platte River. Basin Electric Power Cooperative agreed to provide a $7,500,000 trust fund to be used to preserve migratory bird habitat in the Big Bend area. Nebraska and NWF then withdrew their objections to issuance of the permit. The trust was called the Platte River Whooping Crane Critical Habitat Maintenance Trust. It is administered by 3 trustees, 1 selected by each of the major parties to the controversy. The purpose of the Trust is to preserve migratory bird habitat in the Big Bend area of the Platte River. The priority objective is habitat for whooping cranes. The Trust is developing a habitat monitoring program for the Big Bend area and has purchased approximately 1,000 ha (2,500 acres) adjoining 6.5 km (4 mi) of river as part of its program to preserve habitat.

ORIGIN

The Platte River Whooping Crane Critical Habitat Maintenance Trust was the result of an out-of-court settlement of a suit that involved the Basin Electric Power Cooperative, the state of Nebraska, and National Wildlife Federation. The controversy arose as a result of Basin Electric's plan to build a reservoir on the Laramie River, a tributary of the North Platte River, and to divert water to their coal-fired Laramie River Power Station. The power plant would use approximately 23,250 acre-feet of water annually.

The state of Nebraska and the National Wildlife Federation contended that this diversion and consumptive use of water would have adverse impacts on Nebraska resources including the migratory bird habitat in the Big Bend area of the Platte River. This river reach supports 5 to 7 million migrant brids each year including the Aransas National Wildlife Refuge-Wood Buffalo National Park flock of whooping cranes. Based on the use of the area by an endangered species, the whooping crane, and the Endangered Species Act which prohibits a federal agency from taking an action which further threatens an endangered species, the state of Nebraska and NWF objected to the issuance of a 404 permit for the construction of Grayrocks Dam. They pursued this objection by filing suit against the Corps of Engineers to prevent the issuing of a permit.

Much of the work on the Laramie River Station had been completed before the advent of the 404 permit requirement. Although the plaintiffs had made their objections to water diversions from the Platte River system known before, the requirement for a 404 permit provided an effective legal lever which they used to obtain an injunction against further work on the project. The effective date of the injunction provided some time for additional negotiations.

Almost no 1, including the plaintiffs, actually wanted construction on this project stopped, and especially not abandoned. Stoppage of the project would have cost Basin Electric millions of dollars, many workers would have been put out of work with practically no notice, and local governments would have been severely impacted. Stopping the project would also cause serious repercussions for the plaintiffs, not the least of which would be increasing pressures for changing or abandoning the Endangered Species Act. The reality of the situation dictated a compromise, but it was not easy to develop. The suit had been bitter, each side was suspicious of the other, and the time to develop a compromise was short. Fortunately for all sides a compromise was reached and approved by the court.

One of the major parts of that compromise was the formation of the Platte River Whooping Crane Critical Habitat Maintenance Trust, commonly called the Platte River Trust. The purpose of this trust, as described in the court-approved "Trust Declaration" is to ". . . protect and maintain the migratory bird habitat in the so-called Big Bend area of the Platte River between Overton and Chapman, Nebraska." This area contains habitat that is essential to the well-being of whooping cranes, sandhill cranes (*Grus canadensis*), and millions of migratory waterfowl. The biological significance of this area is described by the U.S. Fish and Wildlife Service (1981).

ADMINISTRATION

The Trust is administered by 3 trustees, 1 appointed by each of the principal parties to the controversy. The state of Nebraska is represented by Richard E. Spelts, Jr. of Grand Island, Nebraska; Basin Electric Power Cooperative is represented by James L. Grahl of Bismarck, North Dakota; and the NWF is represented by John J. Cavanaugh of Omaha, Nebraska. The trustees serve at the discretion of their respective organizations. Mr. Spelts serves as chairman.

When the Trust was established, the court ordered Basin Electric Power Company to convey to the Trust a sum of $7,500,000. The payment of this sum to the Trust fulfills Basin Electric Power Cooperative's obligation to the Trust. No other payments are required.

These funds are invested according to an investment strategy approved by the court. The trustees are free to use the income from this fund to pursue the purposes of the Trust and may, if all 3 trustees agree, spend all or part of the principal of the Trust. The Trust Declaration provides only 1 specific task for the trustees, and that is the development of a habitat monitoring plan. This preliminary monitoring plan is described by Ellis and Shoemaker (this proceedings). The trustees established the offices of the Trust in Grand Island, Nebraska, and hired an executive director and a secretary.

OBJECTIVES AND POLICIES

To provide direction to the effort, the Trust developed a set of objectives and a number of policies.

OBJECTIVES OF THE TRUST

1. Foster the continued existence of that amount of habitat required to meet the need of whooping cranes stopping in the Big Bend of the Platte River on their spring and fall migrations.

2. Restore and maintain Platte River habitat for the staging needs of the existing population of greater (*G. c. tabida*), Canadian (*G. c. rowani*), and lesser (*G. c. canadensis*) sandhill crane staging in the Big Bend area of the Platte River.

3. Manage lands under the protection of the Trust in a way that will, within the limits imposed by objectives 1 and 2, meet the needs of other migratory birds, particularly endangered or threatened species.

4. Manage lands under the protection of the Trust in a way that will maintain existing agricultural and other traditional uses of the land insofar as such use is consistent with objectives 1, 2, and 3.

5. Develop and maintain a Platte River migratory bird habitat monitoring program.

6. Provide a local focus for information on the status and importance of the Platte River for migratory birds.

7. Act as a catalyst to promote research that would improve our understanding of the needs of whooping cranes and other migratory birds using the Platte River.

The primary objective of the Trust is to provide habitat for whooping cranes that migrate through the Big Bend area of the Platte River. Providing for the needs of sandhill cranes and other migratory birds is secondary to this objective; however, in practical biological terms, meeting the needs of whooping cranes accommodates the needs of these other birds.

The reason for objective 4 will become evident after a discussion of Trustees Policies. Objective 5 is directed to obtaining the information needed to describe the problem and develop action programs. The success of the Trust is dependent to some extent on public acceptance of Trust programs; objective 6 is directed toward that end. Much is unknown about Platte River ecology. More research is needed and although the Trust cannot afford to fund extensive research efforts, it hopes to facilitate research when it can.

POLICIES OF THE TRUST

It is the policy of the Trust to do the following:

1. Maintain a minimum balance in the Trust's investment protfolio to insure a level of interest

income and earnings sufficient to pay the administrative costs of the Trust. The trustees shall review this minimum balance annually to determine the need to adjust it to compensate for the deflated value of the dollar, increased administrative costs, or inadequate earnings.

2. Consider the funding source for land acquisitions on a case by case basis. (This policy may change after the development of a long-term action plan by the Trust.)

3. Generate all funds for management and maintenance of Trust-protected lands through earnings from agricultural land-use or user fees.

4. The Trust will maintain the highest agricultural uses of its lands that are consistent with the needs of whooping cranes and other migratory birds using the area.

5. The recreational, educational, and commercial uses of Trust-protected land will be determined on a case by case basis. On those lands where such uses are allowed, their management will be financed in total by user fees or contributions made for that particular use.

6. The Trust will utilize those federal and state assistance programs that can contribute to the attainment of Trust objectives.

Trust policies tell more about the direction of the Trust than do the objectives. Policy 1 indicates the Trust is intending to operate in perpetuity. Policy 2 will change after a long-range plan has been developed. This long-range plan will be based on the analyses of habitat need identified through the use of the habitat model described by Armbruster and Farmer (this proceedings). Policy 3 states that all Trust-owned properties must be self-sustaining. This means that Trust funds may be used to purchase land or water but all maintenance costs, including taxes and management costs, will be paid for by earnings from property or fees charged for particular uses. The Trust presently owns 2 tracts; 1 is primarily grass and hayland and is used for grazing and haying. These uses will pay for management and maintenance costs. The 2nd tract is cropland. Although we intend to change the land-use on this tract, agricultural revenues from the planned use will pay for all costs associated with it.

Agriculture is not only the principal economic activity of the Big Bend area of Nebraska, it is also the basis of its culture. The agricultural land-use ethic is the dominant theme of the area and good neighbors adhere to this land-use ethic. For this reason, the Trust has adopted Policy 4. It states the Trust will maintain the highest agricultural uses of its lands consistent with the needs of whooping cranes, sandhill cranes, and other migratory birds.

Although the Trust wishes to provide for some public use of Trust lands, it believes that Trust funds should not be used to support these uses. Therefore, the trustees have adopted Policy 5 which states, "all public uses of the area (except guided tours conducted during spring migration) will be on a fee basis." As a private organization, the Trust can take advantage of several state and federal programs designed to aid the private landowner. Policy 6 recognizes that such programs will be used when they are compatible with Trust objectives and policies.

LONG-RANGE PLANNING

The next major step the Trust will take is approval of a long-range plan. This plan will quantify the habitat maintenance goals of the Trust and describe the methods the Trust will use to pursue those goals. In setting the habitat maintenance objectives, the Trust will translate crane population numbers into amounts of habitat required. This quantification will be based on the habitat model described by Armbruster and Farmer (this proceedings). We envision a basic habitat unit that will include riverine, wetland, grassland, and cropland elements. A habitat unit will be the smallest complex that can provide the life requisites for a given number of staging sandhill cranes. The total habitat requirement will be calculated by dividing this number of staging cranes into the total population and multiplying the acreage figures in 1 habitat unit by the resulting multiplier. The Trust will then attempt to protect this amount of habitat in the Big Bend area. The Trust will consider purchase, easements, or long-term leases of land.

Water to maintain flows in the Platte is a critical issue which the Trust is now examining. No strategies for preserving flows have been adopted.

The Platte River Trust is a unique organization. Many are watching its progress to see if this kind of mechanism is a viable way of solving environmental problems. We expect to be successful.

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SUSCEPTIBILITY OF THE MIDCONTINENT POPULATION OF SANDHILL CRANES TO AVIAN CHOLERA IN NEBRASKA--A PRELIMINARY REPORT

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Abstract: Large losses of waterfowl to avian cholera have occurred in the Rainwater Basin Area of south central Nebraska during March of several recent years. These losses, including a verified loss of nearly 31,000 waterfowl in 1980, have prompted concern for the welfare of the midcontinent population of sandhill cranes (*Grus canadensis*) during their annual spring stopover along the Platte River. Specific concerns include the close proximity of infected wetlands to major crane roosts, crowding of cranes into restricted reaches of river because of widespread channel shrinkage and associated encroachment by woody vegetation, and the likelihood of a major shift of cranes to the basin wetlands if habitat conditions continue to deteriorate in the Platte Valley. This paper reviews available information on the epizootiology of avian cholera in migratory bird populations and discusses prospects for transmission of avian cholera to the midcontinent sandhill crane population.

Marked shrinkage of channels of the Platte River during the past 40 years (Williams 1978) and associated encroachment by woody vegetation (Currier 1981) have confined the midcontinent sandhill crane population to restricted reaches of riverine habitat during their annual spring stopover in the Platte River Valley. Nearly 400,000 sandhill cranes gather along the "Big Bend" reach of the river for several weeks each spring (E. Ferguson, unpubl. manuscript) and occur at densities which in some areas now exceed 5,000 cranes per 0.8 km of channel (Frith and Faanes, this proceedings). The present paper was prepared as part of the Platte River Ecology Study to provide an improved perspective of the potential significance of channel habitat loss to the midcontinent sandhill crane population. This assessment was prompted by recent major outbreaks of avian cholera in waterfowl populations using the Rainwater Basin Area in south central Nebraska near reaches of the Platte River where large numbers of sandhill cranes roost.

The authors thank the Director and staff at the National Wildlife Health Laboratory at Madison, Wisconsin, for their critical review of the manuscript. In particular, we wish to thank Dr. M. Friend and C. Brand for their helpful suggestions. We also wish to thank A. Trout, Manager of the Rainwater Basin Wetland Management District and his staff, and J. Hurt of the Nebraska Game and Parks Commission for providing information on avian cholera outbreaks occurring in the Rainwater Basin Area.

DESCRIPTION OF THE DISEASE

Avian cholera is an infectious disease caused by the bacterium *Pasteurella multocida*. It has been reported in a wide variety of domestic and wild birds (Rosen 1971, Heddleston 1972). Outbreaks in wild birds have most frequently been reported in waterfowl (Rosen 1971), but avian cholera also has been reported in the bald eagle (*Haliaeetus leucocephalus*) and other raptors (Rosen and Morse 1959, Hunter 1967, Rosen 1971, Rosen 1972). Ten sandhill cranes among a wintering population of 5,600 died in a 1970-71 avian cholera outbreak in California (Rosen 1972). Individual sandhill cranes have died of avian cholera in Nebraska along the Platte River during the spring of 1975 (James Hurt pers. comm.), and on a Rainwater Basin wetland in the spring of 1977 (Christ Brand pers. comm.). Avian cholera has not been diagnosed in whooping cranes (*Grus americana*), but the wide host range of *P. multicoda* in birds indicates that whooping cranes must be presumed to be susceptible to the disease (Zinkl et al. 1977).

In migratory birds, avian cholera typically is an extremely acute disease, with few signs being evident other than dead birds (Jensen and Williams 1964, Rosen 1971). Few sick birds usually are seen and they frequently die shortly after signs appear (Rosen and Bischoff 1949, Jensen and Williams 1964, Rosen 1971, Zinkl et al. 1977). Waterfowl displaying disturbances of equilibrium and other neurological signs may be seen occasionally as outbreaks progress (Rosen and Bischoff 1949, Jensen and Williams 1964, Vaught et al. 1967, Rosen 1971, Zinkl et al. 1977). In common crows (*Corvus brachyrhynchos*), however, avian cholera may occur in a chronic form (Zinkl et al. 1977). Healthy appearing, chronically infected *P. multocida* carriers occur in domestic poultry and are believed to be important in maintaining the infection and serving as the source of new outbreaks (Heddleston 1972). Chronically infected carriers may also occur among survivors of avian cholera outbreaks in migratory birds (Jensen and Williams 1964, Vaught et al. 1967, Donahue and Olson 1969, Rosen 1971), and Korschgen et al. (1978) found a low incidence of *P. multocida* carriers in common eiders (*Somateria mollissima*).

DISEASE DISSEMINATION

Dissemination of *P. multocida* among birds occurs via nasal exudates which contaminate the environment, especially food and water (Rosen 1971, Heddleston 1972); feces are a much less significant source of contamination (Heddleston 1972). The nasal exudate of diseased birds contains large numbers of *P. multocida* (Rosen 1971, Heddleston 1972) and copious quantities of this material may drain from the bills of birds immediately upon death (Rosen 1971).

The most common routes of infection for *P. multocida* in birds probably are by ingestion or inhalation, with the organism gaining access through the mucous membranes of the mouth, pharynx, and upper air passages (Heddleston 1972) based on experimental studies of domesticated poultry. Infection also may occur via the eye (Heddleston 1972). Contaminated water, therefore, is thought to be an important source of infection, especially for waterfowl (Rosen 1971) but contaminated food also may be a source (Rosen 1971, Heddleston 1972).

DISEASE OCCURRENCE IN NEBRASKA

The 1st confirmation of avian cholera in migratory birds in Nebraska occurred in waterfowl and crows in the Rainwater Basin Area in 1975 (Zinkl et al. 1977). An estimated 20,000-25,000 waterfowl died in the 1975 outbreak in the Rainwater Basin Area (Zinkl et al. 1977), 7,500-8,500 were estimated to have died in the spring of 1976, and 7,500-10,000 in the spring of 1977 (A. Trout, unpubl. data). Losses in the Rainwater Basin Area were low in the spring of 1978, but 3,100 birds, primarily American coots (*Fulica americana*), died of avian cholera on Lake McConaughy and at the Swanson Reservoir in Hitchcock County (Hurt 1978). Losses were low again in 1979, but in the spring of 1980 avian cholera occurred on numerous wetlands in the Rainwater Basin Area and nearly 31,000 dead waterfowl were collected (Friend 1981). Sites of heavy waterfowl mortality and their distribution in relation to sandhill crane staging habitat along the Platte River are shown in Fig. 1.

FACTORS CONTRIBUTING TO CHOLERA OUTBREAKS

Numerous factors have been suggested as contributing to avian cholera outbreaks in birds. In domestic poultry, withdrawal of feed and water, abrupt changes in diet, and environmental stress are reported to increase the incidence of avian cholera (Heddleston 1972). No correlation, however, was found between temperature and the mortality rate in the 1949-50 Texas outbreak in migratory waterfowl, although an apparent correlation was noted with wind (Petrides and Bryant 1951).

Bennett and Bolen (1978) found a correlation between wind velocity, relative humidity, and a stress repsonse in wintering green-winged teal in Texas. The 1970 outbreak on Chesapeake Bay was preceded by several weeks of extremely cold weather (Locke et al. 1970). The 1964 outbreak at the Squaw Creek National Wildlife Refuge was associated with cold temperatures, a corn diet, and lead poisoning in mallards (H. C. McDougle et al., unpubl. rep.). The 1975 Nebraska outbreak was preceded by a brief snow storm (Zinkl et al. 1977). However, no cause and effect relationship has been demonstrated between any of the aforementioned factors and the occurrence of avian cholera.

Nutrition has been suggested as an important factor in avian cholera (Rosen and Bischoff 1950), and outbreaks in common eiders occur during the nesting season when female eiders may lose up to 50% of their body weight (Korschgen et al. 1978). Avian cholera apparently also occurs in snow geese on their Canadian nesting grounds when females undergo weight loss during laying and incubation. However, diet had no apparent influence in the 1949-50 outbreak in waterfowl in Texas (Petrides and Bryant 1951) and, in fact, waterfowl dying in avian cholera outbreaks frequently are in excellent condition with abundant fat deposits (Quortrup et al. 1946, Vaught et al. 1967, Locke et al. 1970, Zinkl et al. 1977, Wobeser et al. 1979). Rosen (1971) postulated that the improving physical condition of waterfowl in spring as they are preparing to migrate to northern nesting grounds might be an important factor in preventing winter avian cholera outbreaks in California. However, the persistence of avian cholera within waterfowl undergoing rapid fat deposition on the spring staging area in Nebraska would appear to discount this hypothesis.

No consistent correlation exists between the total numbers of birds present and the total mortality in avian cholera outbreaks among migratory birds (Rosen 1969, 1971). Apparently the sever-

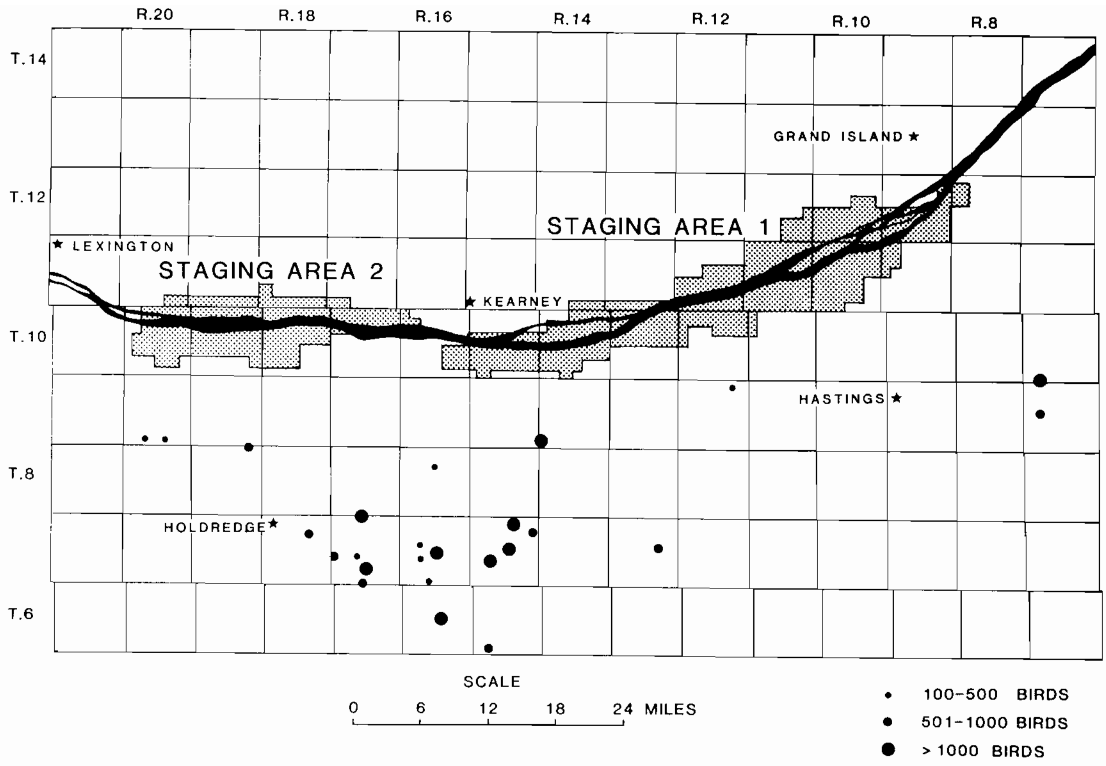

Fig. 1. Distribution of avian cholera outbreaks in the Rainwater Basin Area during spring 1980 and proximity to spring staging areas of sandhill cranes (shaded). Size of each closed circle identifies magnitude of bird loss at a particular site.

ity of outbreaks is influenced by factors other than population size. However, high bird densities are presumed to facilitate transmission of contagious diseases (Rosen and Bischoff 1950, Jensen and Williams 1964), and overcrowding and "concentration" frequently are cited as factors associated with avian cholera outbreaks in migratory waterfowl (Rosen and Bischoff 1950, Petrides and Bryant 1951, Klukas and Locke 1970). The 1970 outbreak on Chesapeake Bay occurred when sea ducks concentrated on shallow portions of the bay after cold weather (Locke et al. 1970).

The maintenance of open water by pumping at the Squaw Creek National Wildlife Refuge concentrated an estimated 300,000 waterfowl on small water areas and was thought to be an important factor in the 1964 outbreak (H. C. McDougle et al. unpubl. rep., Vaught et al. 1967). Late fall flooding followed by winter drought, which resulted in a decrease in the number and size of water areas and the concentration of waterfowl, was associated with the loss of an estimated 37,000 waterfowl in California in 1970-71 (Rosen 1972). High bird densities were cited as a factor in avian cholera outbreaks among nesting common eiders (Korschgen et al. 1978).

Low water conditions and spring storms which delayed migration were cited as factors which may have concentrated waterfowl in Nebraska during the spring of 1975, contributing to an outbreak of avian cholera (Zinkl et al. 1977). However, Rosen (1969) explains that ". . . population density is considered important in the transmission of disease per se, but another factor is not the total population of the waterfowl or of any one species, but rather how locally concentrated they are." However, studies relating actual bird densities to either total mortality or mortality rate in migratory waterfowl have not been reported, so the relationship remains unconfirmed.

Another major deficiency in understanding the epizootiology of avian cholera in migratory birds is the absence of information relating the occurrence and magnitude of outbreaks to the immune status of the populations involved. The pattern of the recent avian cholera mortalities in migratory waterfowl in Nebraska (an initial severe outbreak in 1975, followed by 2 years of reduced losses, 2 years of relatively low losses, and then another large outbreak in 1980) may reflect changes in immunity status among populations involved.

High losses would be expected in the 1st outbreak, because few individuals would be immune. Losses in subsequent outbreaks would continue at moderate levels until a substantial portion of the population had been exposed, followed by a decline in mortality to a very low level. As the immunity level of the population waned, or as recruitment replaced the immune birds, a susceptibe population might then initiate another large outbreak.

The 5-year interval between the serious outbreaks in 1975 and 1980 is compatible with the fluctuating immune status which would be expected in a migratory waterfowl population. Fluctuating levels of immunity within migratory bird populations might explain the difficulty of demonstrating consistent relationships between environmental factors and outbreaks, the variations in mortalities from year to year independent of total bird numbers, and variations in mortality rates within species during different outbreaks.

In view of the lack of definitive findings showing cause and effect relationships, additional research is needed to identify the conditions that contribute to spread of the disease in wild populations of migratory birds.

POTENTIAL IMPLICATIONS TO THE SANDHILL CRANE POPULATION

An assessment of the impacts of changing habitat conditions on the occurrence and magnitude of outbreaks will necessarily remain conjectural until the combined relationships of environmental stresses, bird density, habitat utilization, and immunity to avian cholera in migratory birds are better understood. Nevertheless, certain assumptions are warranted regarding avian cholera in migratory birds on the Platte River Study Area.

It is evident that avian cholera is now established within the migratory waterfowl and crow populations which gather in south central Nebraska during early spring. Experience with avian cholera in migratory waterfowl in Texas and California (Jensen and Williams 1964, Rosen 1971), off the coast of Maine (Korschgen et al. 1978), in the Chesapeake Bay area (Locke et al. 1970, Pursglove et al. 1976), and in Saskatchewan (Wobeser et al. 1979, Friend 1981) indicates that, after a pattern of outbreaks has been established, the disease can be expected to recur. Avian cholera has now occurred in migratory waterfowl and coots in Nebraska in each of the last 6 years.

It can also be assumed that all species of birds present are susceptible to avian cholera including sandhill and whooping cranes, bald eagles, and other raptors (Rosen 1971, Zinkl et al. 1977). Exposure will vary among species and be dependent upon their occurrence on outbreak areas, the specific subhabitats occupied, food habits, and level of association with and exposure to infected birds.

With avian cholera established in migratory bird populations using the Rainwater Basin Area, it can be assumed that habitat changes which would increase the densities of birds or the level of association between flocks and species of birds, or both, will magnify losses or the occurrence of the disease in different species. Although high bird densities per se do not cause disease outbreaks, they may contribute to the development of these outbreaks by increasing the number of carriers at a specific location. Shedding of disease organisms into dense concentrations of birds facilitates transmission of contagious pathogens when suitable environmental conditions exist. If shrinkage of the wetland habitat base continues in the Rainwater Basin Area, it will very likely increase the densities of waterfowl on remaining wetlands and increase the potential for transmission during avian cholera outbreaks.

Wetland habitat destruction in the Rainwater Basin Area also can be expected to increase the level of association between waterfowl and other species of migratory birds, e.g., whooping cranes and possibly sandhill cranes in the future, increasing their exposure to avian cholera. If loss of Rainwater Basin wetlands results in major shifts of the waterfowl population to the Platte River, this shift would increase the level of association with the sandhill crane population and increase its exposure to avian cholera. With inadequate flows in the Platte, the potential for high losses would exist on the River.

Loss of approximately two-thirds of the river channel as roosting habitat for sandhill cranes has resulted in high densities of birds on the remaining suitable areas (Frith and Faanes, this proceedings). Dilution and dispersal of the bacterium varies directly with volume of water passing through the channel; consequently, reduced flows significantly affect exposure even when numbers and distribution of birds do not change. If sandhill cranes moved to the Rainwater Basin Area in response to loss of roosting habitat on the Platte River their level of association with waterfowl would increase as would their vulnerability to avian cholera.

Habitat deterioration caused by encroachment of woody vegetation in channels of the Platte River, if not controlled, will probably cause the sandhill crane population to move from the present staging areas. The Rainwater Basin Area, where avian cholera outbreaks have become common in waterfowl, is a potential alternative stopover site for the cranes. A shift by whooping cranes to the Rainwater Basin Area has already occurred (Johnson, this proceedings) and knowledge that sandhill cranes readily occupy similar habitat elsewhere along their migration route, plus observations of flocks of sandhill cranes on certain federally owned waterfowl production areas in the Basin Area (Harvard, Massie, McMurtry, Clark, Hansen, and Prairie Dog)(A. Trout pers. comm.) adds to the plausibility of this scenario being realized.

If a reduction occurs in the acreage of harvested corn and other grains, it can be expected to cause increased bird densities and more frequent association of different species on upland feeding sites and wetlands where food is most plentiful. Although water appears to be a major vehicle for transmission of avian cholera in waterfowl (Rosen 1971), transmission may also occur by contaminated food (Rosen 1971, Heddleston 1972). Contaminated food could become an important source of infection especially if large numbers of infected waterfowl were to feed in fields being utilized by sandhill or whooping cranes.

The most serious threat would exist for both cranes and waterfowl if habitat conditions along the Platte continue to deteriorate and flows cease during spring. With the combination of high population densities and high levels of association between populations in a nonflowing channel environment, avian cholera outbreaks very likely would involve virtually all species, i.e., waterfowl, cranes, and eagles, with little prospect for control and with mortalities being limited only by the natural course of the epizootic.

Maintaining adequate flows in the Platte to meet needs of cranes and waterfowl may represent the only possible prospect for controlling migratory bird losses to avian cholera. However, additional information is needed before a definitive management plan can be developed to control avian cholera in south central Nebraska. Research has been proposed by the U.S. Fish and Wildlife Service's National Wildlife Health Laboratory to address the problem. These studies would necessarily involve research on the epizootiology of the disease and studies directed toward gathering adequate base-line information on migratory bird usage and movements in the Rainwater Basin Area and between the basins and the Platte River.

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INVENTORY OF SANDHILL CRANE ROOSTING HABITAT ON THE PLATTE AND NORTH PLATTE RIVERS, NEBRASKA

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Abstract: Determination of the distribution of roosting sandhill cranes (*Grus canadensis*) along the Platte and North Platte Rivers in Nebraska is a prerequisite to fully assess habitat needs and interpret the significance of existing habitat conditions. During the spring of 1979, an aerial inventory was conducted to locate all sandhill crane roosting areas and to determine their magnitude of use. Fifteen early morning aerial surveys revealed that roosting use occurred on 137 of 406 census areas. One hundred and five of 299 census areas on the Platte River, and 32 of 107 census areas on the North Platte River were used for roosting. About 30% of the 105 roosting areas on the Platte River contained 1 to 1,000 cranes. About 51% of 105 areas were used by 1,001-5,000 cranes, and 18% of the areas contained over 5,000 cranes. Similar analysis of the North Platte River indicated about 37% of 107 areas contained 1 to 1,000 cranes. About 53% of the areas were used by 1,001-5,000 roosting cranes, and 9% had over 5,000 roosting cranes. The Mormon-Shoemaker Islands area had the highest density per kilometer of the major roosting areas along the Platte and North Platte Rivers.

Portions of the Platte and North Platte Rivers of central Nebraska support the largest known spring concentration of sandhill cranes on the North American Continent. Frith (1974) compared the North American range of sandhill cranes to an hourglass with the top being the nesting grounds, the bottom the wintering area, and the restricted portion the Platte River spring staging area.

U.S. Fish and Wildlife Service (1981) estimated that the maximum size of the sandhill crane population along the Platte and North Platte Rivers ranged from 306,000 to 541,000 in 1979 and 1980. Most of these birds are the lesser (*G. c. canadensis*) and the Canadian (*G. c. rowani*) subspecies. Lewis (1977) estimated that of the total continental population of lessers, about 20,000 winter in California. Of the lesser and Canadian races, all but the California birds stage annually along the Platte and North Platte Rivers during March and April. Several thousand greater sandhill cranes (*G. c. tabida*) also stop along the eastern edge of the Platte River staging area (Guthery and Lewis 1979:122) when migrating between their nesting grounds in Manitoba and wintering area along the Texas Gulf Coast (Melvin and Temple 1980).

Wheeler and Lewis (1972) and Lewis (1979) reported that the number of sandhill cranes censused along the Platte River varies annually. Those authors found that sandhill cranes occur primarily in 3 sections of the Platte River: Grand Island to Lexington, North Platte to Sutherland, and the west end of Lake McConaughy to Lewellen. The mean number of cranes per lineal kilometer of river for the 3 areas was 944, 1,076, and 324, respectively, in 1968.

This report summarizes the results of a study designed to locate all sandhill crane roosting areas, and to determine the magnitude of use each area received.

STUDY AREA

That portion of the area within the Platte River system used by sandhill cranes and reported on in this study encompasses the Platte and North Platte Rivers beginning south of Chapman on the Platte then upstream (west) to Kingsley Dam (Lake McConaughy) on the North Platte River. A map of the study area can be found in the article by Faanes and Frank (this proceedings). The study area lies adjacent to or within the counties of Hamilton, Merrick, Hall, Adams, Buffalo, Kearney, Dawson, Phelps, Gosper, Lincoln, and Keith. Most of the use area is within the "Big Bend" reach of the Platte River.

Most land within the study area is in private ownership. Present land use is predominately agricultural, and includes about 15% riparian woodland, 5% tame pasture, 20% native grassland, and 60% cropland (Reinecke and Krapu 1979). A general description of the hydrology and native vegetation is provided by Williams (1978) and Currier (1981), respectively.

METHODS

To determine sandhill crane densities and distribution at roosting sites the 468-km reach of these rivers between Chapman and Kingsley Dam was delineated into 406 0.8-km consecutive units. Sample areas were plotted on 7.5-minute (U.S. Geological Survey [USGS]) quadrangle maps. Sample area 1 began at the Chapman Bridge (Merrick County) on the Platte River and sample area 406 ended at Kingsley Dam (Keith County) on the North Platte River. These census areas were categorized to correspond to their geographical setting. For example, areas 25 through 59 were referred to as the Mormon-Shoemaker Islands area.

Prominent geographical landmarks and riverine features were transferred from the USGS 7.5-minute quadrangle maps to field data sheets to form navigational and recording aids while conducting the aerial censuses. A roost site was designated as the entire reach of river between 2 bridges. This distance varied from 9.6 to 20.9 km along the Platte River and greater distances on the North Platte River. Our census estimates were made from a Cessna 172 aircraft beginning approximately 30 minutes before sunrise.

RESULTS

Our surveys revealed that sandhill cranes roosted on 137 of 406 sample areas (33.7%). One hundred and five of 299 sample areas (35.1%) were used for roosting on the Platte River and 32 of 107 sample areas (29.9%) were used on the North Platte River.

On 32 of the use areas (30.5%) between Chapman and Lexington, there were 1 to 1,000 cranes roosting per area. Fifty-four areas contained 1,001-5,000 roosting sandhill cranes (51.4%), and 19 areas (18.1%) supported over 5,000 roosting sandhill cranes (Table 1). Use was substantially less along the North Platte River. On 12 areas (37.5%) there were 1 to 1,000 sandhill cranes. Seventeen areas (53.1%) supported 1,001-5,000 sandhill cranes and 3 areas (9.4%) had over 5,000 sandhill cranes.

Table 1. Sandhill crane roosting use of the Platte River from Chapman to Lexington and use of the North Platte River from its confluence with the South Platte River upstream to Lake McConaughy, Nebraska, 1979.

Location	Cranes per 0.8 km			Total
	1-1,000	1,001-5,000	5,000+	
Platte River				
Census areas	32	54	19	105
Percent use of area	30.5	51.4	18.1	100.0
North Platte River				
Census areas	12	17	3	32
Percent use of area	37.5	53.1	9.4	100.0

Maximum use varied considerably between sample areas within each geographical location. Use also varied considerably between major roost concentration areas. The Mormon-Shoemaker Islands area (areas 25-59) had the highest density (2,480 sandhill cranes per kilometer) followed by the Wood River-Shelton area (areas 62-82) with 1,120 sandhill cranes per kilometer. Other areas such as the Fort Farm-Killgore Islands (83-107), Kearney-Fort Kearney (108-131), Odessa-Elm Creek (132-147), and Overton-Jeffrey Island (157-169) had 2,105, 121, 1,425, and 325 sandhill cranes per kilometer, respectively. The Hershey area (areas 311-347) contained 1,197 cranes per kilometer.

DISCUSSION

The future of the sandhill crane resource is dependent on preservation of its habitat along the Platte and North Platte Rivers. Roosting habitat is restricted to those portions of the river that have undergone the least amount of change, primarily vegetative encroachment which increases permanent vegetation on river islands within the channel. This encroachment phenomenon results from reducing annual peak flow in the river because of upstream water withdrawal activities (Frith 1974). Because sandhill cranes prefer open areas for roosting, water withdrawal is detrimental and, if continued, will eliminate areas which are currently used by small numbers of sandhill cranes. Channel deterioration resulting in reduced roosting habitat within the high density areas such as Mormon-Shoemaker Islands, Wood River-Shelton, Fort Farm-Killgore Islands, Odessa-Elm Creek, and Hershey could produce a detrimental effect on the entire population.

Habitat conditions appear to have remained stable before 1880 when intensive irrigation of surrounding uplands began. Present conditions have changed the habitat considerably along the Platte and North Platte Rivers. These changes appear to be further restricting sandhill crane use of the area. Frith (1974) indicated that maximum sandhill crane roost areas were within reaches of the Platte River that had undergone the least amount of change through vegetative encroachment. This encroachment appears to be the most serious problem confronting sandhill cranes along the Platte River (Krapu 1979).

Frith (1974) reported that water withdrawal activities have affected the Platte River in the past and will continue to affect it in the future. Kroonemeyer (1979) indicated that predevelopment flow of the Platte River at Overton was 2,600,000 acre-feet at the turn of the century, compared to the present average annual flow of about 800,000 acre-feet. The present flow is 69% less than the predevelopment flow.

Contrasting flow criteria and associated sandhill crane use are evidenced by the conditions occurring at Brady, Nebraska. The present flow at Brady, 77.2 km upstream from Overton, is estimated to be about 420,000 acre-feet annually, or about 84% less than predevelopment flow (Kroonemeyer 1979). Near Brady, water is diverted into a series of reservoirs and canals for power production and irrigation purposes with a portion being returned to the river above Overton. This stretch of river downstream to near Overton is now devoid of crane use.

Williams (1978) studied a 480-km reach of river extending from Minatare on the North Platte River to Grand Island on the Platte River (which includes the Brady to Overton stretch), and found that most river channels have changed considerably. Changes in the 365-km stretch from Minatare to Overton differ in magnitude and sometimes in character from the downstream stretch from Overton to Grand Island. Williams (1978) found that by 1969 the Minatare-Overton reach was only about 0.1 to 0.2 as wide as in 1865. In 1969, the channel in this reach was less braided and slightly more sinuous than the 1938 channel. From Overton to Grand Island, the 1969 channel was approximately 0.6 to 0.7 as wide as in 1865, and changes in braiding and sinuosity took place between 1938 and 1969. Williams (1978) concluded that changes in channel width were related to decreases in water discharge caused primarily by the regulating effects of major upstream dams and the greater use of river water by man.

The latter statements are supported by recent studies concerning loss of open water and barren sandbar habitat from 1938 to 1965 or 1969 (U.S. Fish and Wildlife Service, Grand Island, Nebraska, unpubl. data). These studies compared the loss of open water and barren sandbar habitat within a 21.1-km reach of the North Platte River from near Hershey to near North Platte; a 108-km reach of the Platte River east of North Platte to near Lexington; and a 143-km reach of Platte River east of Lexington to Chapman, Nebraska. Losses of open water and barren sandbar habitat along these reaches of river amounted to about 67%, 81%, and 45%, respectively. These losses of open water and barren sandbar were replaced almost entirely by woody vegetation.

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MORMON ISLAND CRANE MEADOWS - PROTECTING HABITAT FOR CRANES ALONG THE PLATTE RIVER, NEBRASKA

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Abstract: In December 1979, nearly 810 ha (the Mormon Island Crane Meadows [MICM]) of prime habitat for spring-staging migratory water birds were acquired in Nebraska through a cooperative effort of The Nature Conservancy (TNC) and the Platte River Whooping Crane Critical Habitat Maintenance Trust. Through a lease agreement with the Trust, TNC is responsible for developing a management plan for the site. The specific management objectives are to maintain or enhance the habitat for whooping cranes (*Grus americana*) and sandhill cranes (*Grus canadensis*), and to restore a native tallgrass plant community. An inventory of the flora and fauna on MICM has to date identified nearly 1,000 species. A crane observation facility was constructed by the Trust in February 1981 to enable public viewing of sandhill cranes roosting on the river. Plans for the long-term management of the upland habitat include a combination of prescribed burning, grazing, and haying. Upland habitat manipulation studies will commence in 1982 to analyze the effects of management practices on crane use and distribution. Riparian crane roosting habitat will be managed by mechanical control of the woody vegetation in order to maintain open channels and retard encroachment of woody vegetation.

The Platte River Valley has for many decades been recognized as an important congregation area for migratory water birds. Estimates of 5 to 9 million ducks and geese, including 70 to 90% of the midcontinent white-fronted goose (*Anser albifrons*) population, and 80 to 100% of the midcontinental population of sandhill cranes use the Platte and adjacent wetlands each spring (Kroonemeyer 1979). The Big Bend region of the Platte is also a major stopping area for the endangered whooping crane (USFWS 1981). Our understanding of the role the Platte Valley plays as a staging area for cranes has evolved from the early descriptive observations of Walkinshaw (1956) to the modern technical methodologies employed by Melvin and Temple (1980 and this proceedings) and USFWS (1981).

Broad-scale efforts to protect the habitat in key portions of the Platte Valley for the well-being of this international migratory bird resource have largely been unsuccessful (Kroonemeyer 1979). Each year riparian habitat attrition and degradation continues through conversion of meadow areas to intensive agricultural lands and the encroachment of woody vegetation on river channels and islands (Williams 1978, Currier 1981, USFWS 1981). Proposed water diversion projects also threaten to further reduce the meager flows existing in the Platte River system with a potential net effect of accelerating the current rate of degradation. The saying "Time is of the essence" is especially applicable if we are to preserve this unique area.

The greatest local spring concentration of sandhill cranes was in a 17.7-km (11-mi) stretch of the Platte River southwest of Grand Island, Nebraska, in Hall County, including MICM (Frith 1974). Roosting densities of cranes often reached 10,000 birds/0.8 km (0.5 mi) in this area. Frith (1974) classified this section, which was comprised of Mormon and Shoemaker Islands, as pristine. TNC learned of an opportunity to purchase a 5.6-km (3.5-mi) segment of river frontage within this pristine area and was anxious to negotiate with the landowner.

I thank all of those who participated in the resource inventory of MICM. Chuck Frith, Mia Hay, and John VanDerwalker provided some of the observations of crane use of the field control-burned at Lilian Annette Rowe Sanctuary this year. John Quirk and Russ Hettinger allowed us access to areas leased for grazing. Mia Hay drafted the figure and Connie Stroman typed the manuscript. Rex Boner critically reviewed the manuscript.

ACQUISITION

TNC received an option to purchase Mormon Island Crane Meadows (MICM) in April 1979, nearly 8 years after their 1st offer. The price was approximately $1.6 million. In September, TNC contacted the newly formed Platte River Whooping Crane Critical Habitat Maintenance Trust (VanDerwalker, this proceedings) to seek the funds for acquisition. The Trust agreed to the purchase provided they retained title to the property. A 5-year lease agreement was established between the Trust and TNC in which the Conservancy was responsible for developing a long-term management plan for the area. In December 1979, TNC exercised its option to purchase and transferred the title to the Trust as part of the lease agreement.

MICM was purchased with an existing grazing lease in effect. This lease expires 14 March 1982. In the interim, we are developing a management plan which will address research needs, public use,

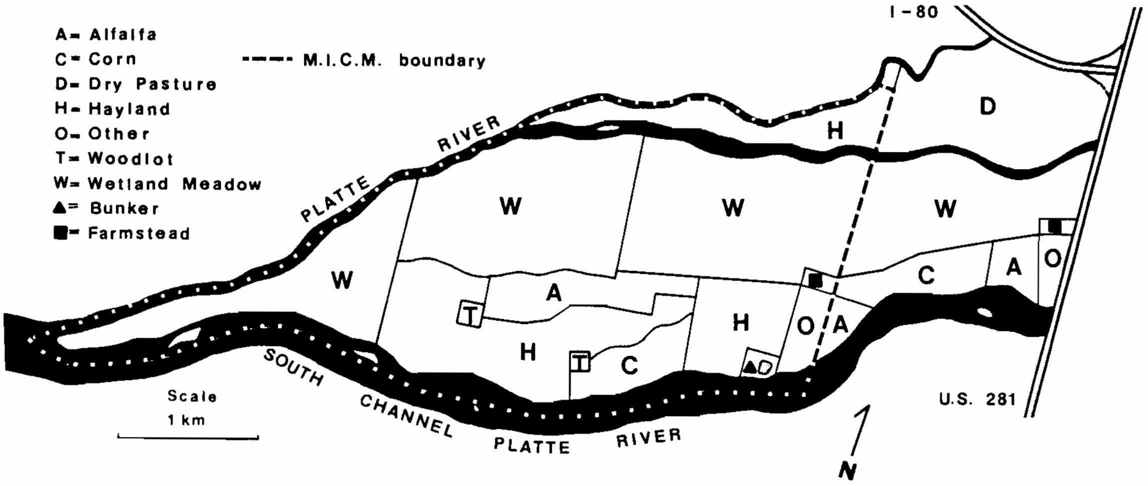

Fig. 1. Habitat types of Mormom Island Crane Meadows and adjacent lands.

and guidelines for future grazing leases. The purpose of this plan is to outline and implement those practices which are compatible with the needs of cranes based on our current understanding of their ecology. Habitat manipulation studies are scheduled to begin March 1982.

RESOURCE INVENTORY

A standard policy of TNC before on-ground management is to inventory the flora and fauna occurring on the preserve so that management objectives can be tailored for that specific site. Such was the circumstance with MICM. Seven phases of this work were contracted to 11 professionals in May 1980. Final reports were received from them in June 1981. The 7 categories studied were: (1) plant community types, (2) floristics, (3) insects, (4) fish, (5) herpetofauna, (6) birds, and (7) mammals. Voucher specimens were housed at the State Museum at Lincoln, Nebraska.

General upland habitat types include approximately 415 ha (1,026 acres) of wetland meadow, 221 ha (545 acres) of native and tame hay, 42 ha (103 acres) of alfalfa, 23 ha (57 acres) of corn, and 30 ha (74 acres) of miscellaneous (Fig. 1). The remaining area is accretion land. A total of 262 plant species was collected on the area (Kolstad 1981). No rare or endangered plants were encountered. Diversity in the grassland was approximately 14 plant species/m^2 (Nagel 1981).

One hundred and thirty-five families of insects were collected. This taxa was well represented and was typical of similar lowland prairie sites (Ratcliffe 1981). The herpetofauna work discovered 10 species. Generally, amphibians were more common than reptiles. The most common amphibians were striped chorus frogs (*Pseudacris triseriata*) and the plains leopard frogs (*Rana blairi*). Six-lined racerunners (*Cnemidophorus sexlineatus*) and garter snakes (*Thamnophis* sp.) were the most abundant reptiles (Ballinger 1980). Thirty-three species of fish (Cochnar and Jenson 1981), 23 species of mammals (Springer 1981), and 177 avian species (Hay and Lingle 1981) were recorded for the area. Two federally listed endangered species of birds, the bald eagle (*Haliaeetus leucocephalus*) and the peregrine falcon (*Falco peregrinus*), were observed, both of which are transients. A maximum of 18 bald eagles was counted in March 1980. The least tern (*Sterna albifrons*), listed by Nebraska's state government as threatened, occurs on riverine islands next to MICM.

Base-line data were collected on sandhill crane use of the MICM area between 14 February and 15 April 1981 (Hay and Lingle 1981). The 1st crane arrived on 14 February. Numbers gradually increased and peaked on 25 March when 31,420 cranes were observed on the wetland meadows. Temporal aspects of sandhill crane use of MICM, roosting densities and distribution, and factors influencing crane behavior are discussed in another paper (Hay and Lingle, in prep.).

MANAGEMENT OBJECTIVES

Two management goals must be attained in order to meet the habitat needs for sandhill and whooping cranes: (1) Maintain low-stature vegetation for feeding and loafing within the upland habitat, and (2) maintain open channel conditions for roosting within the riparian habitat. Prescribed burning can be a useful management tool in providing low-stature vegetation for cranes. Labuda and Butts (1979:151) reported whooping cranes "will exploit recently manipulated (burned, mowed, grazed) upland grass communities from 1 week to 24 months after the treatment occurs." USFWS (1981) found sandhill cranes avoided areas with tall, dense cover. In areas where rank growth was spring burned, sandhill cranes occupied the sites and were feeding on earthworms (USFWS 1981).

Management of the Lillian Annette Rowe Sanctuary of the National Audubon Society near Gibbon, Nebraska, has provided insight in controlled burning as a management tool for cranes. Cranes were immediately attracted to approximately 101 ha (250 acres) of grassland following burns in early April of 1979 and 1980. Two whooping cranes were observed on the 5th day following the burn in 1980 (USFWS 1981). Apparently the availability of a concentrated food source (earthworms in this situation) caused the cranes to congregate on the burned area. On 24 March 1981 the tract was burned again; however, the response by cranes was quite different from previous years. Cranes were not observed using the area on 6 occasions when the tract was checked between 24 March and 11 April although large numbers of cranes were present in the immediate vicinity. Twenty cranes occupied the burned site on 3 April. It may be that the extremely dry and mild weather conditions during the preceding 7 months influenced the local invertebrates to such an extent that they were not accessible like they were after the burns in 1979 and 1980. These observations emphasize the need for several years of study before large-scale management practices are implemented.

Low-stature vegetation in the uplands can be maintained by a combination of mowing, grazing, and prescribed burning. We plan to experimentally assess the relative value of each treatment in terms of crane use. After several years of data are collected, upland habitat management will encompass the best combination of treatments.

The importance of invertebrates in the diet of sandhill cranes has been elucidated by Reinecke and Krapu (1979) and USFWS (1981). Intensive study of invertebrate populations will be done within various treatments to complement crane-use data and provide a better understanding of the ecology of this crane staging area.

The encroachment of woody vegetation in riparian sites has reduced suitable roosting habitat for cranes (Currier 1981, USFWS 1981). Removal of this woody growth will begin in the summer of 1982 on selected sites bordering MICM. Mechanical methods will be used because lack of fuel prohibits the use of fire and use of chemical methods can be hazardous on a riparian system. Cranes prefer channels at least 150 m wide and use diminishes when the channel becomes less than 55 m (USFWS 1981). Mechanical control is a costly undertaking and alternative methods may be applied on an experimental basis.

A broad goal of TNC is maintenance of the full natural diversity of species and communities representative of the grassland biome. The existing condition of MICM's grasslands reflects overuse by cattle and an abundance of introduced plant species. This lowland prairie community along the Platte Valley is jeopardized by conversion to intensive agricultural land. Another management objective is to restore and revitalize the grassland to native prairie.

PUBLIC USE

Public use of the area is restricted and is by reservation only. A sandhill crane viewing facility was constructed by the Trust in February 1981. The bunker-type blind offers visitors a wide panorama of grasslands and overlooks a major roosting concentration of cranes. A portion of the funds for the construction of this facility was generously donated by children from 43 states and 5 Canadian provinces as a result of an article appearing in the March 1980 issue of Ranger Rick magazine. This structure is dedicated to the children of North America. The facility was open to the public on a reservation basis from 7 March to 11 April 1981. The interest in observing cranes was reflected by the enthusiasm and broad geographic origin of the visitors (Table 1). Maintenance costs were defrayed by donations. The blind will be open again this spring between 6 March and 10 April 1982 by reservation.

We hope to stimulate public awareness and appreciation of the Platte River Valley and to maintain MICM in a condition favorable to the tremendous numbers of migratory waterbirds visiting the area each spring. MICM is just a small step towards reaching those goals and assuring the continuance of this natural spectacle.

Table 1. Visitor use of the sandhill crane viewing facility, 7 March - 11 April 1981.

Origin	Number of visitors	Rank	Origin	Number of visitors	Rank
Alaska	2	10	Nebraska	320	1
Arkansas	2	10	New Jersey	1	11
California	3	9	New York	1	11
Colorado	2	10	North Dakota	1	11
Hawaii	2	10	Ohio	1	11
Idaho	1	11	South Dakota	27	3
Illinois	2	10	Washington, D.C.	4	8
Indiana	1	11	Wisconsin	15	6
Iowa	31	2	British Columbia	1	11
Kansas	24	5	England	1	11
Massachusetts	2	10	West Germany	1	11
Minnesota	26	4			
Missouri	8	7	Total	479	

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CHARACTERISTICS OF DIURNAL SANDHILL CRANE FLOCKS IN THE PLATTE RIVER VALLEY, NEBRASKA

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Abstract: During March 1979, extensive observations were made of the numbers of sandhill cranes (*Grus canadensis*) along the Platte and North Platte rivers, from Grand Island to Lexington, and North Platte to Lewellen, Nebraska. Data were collected on the number of individuals occupying a legal quarter section (64.8 ha), habitat use, number and size of flocks, and time of observation in each of 9 census areas. Largest numbers of sandhill cranes occupied the Platte River during the latter 2 weeks of March in 1979. Sandhill cranes apparently occur in largest flocks during 1200-1300 hours. Our data suggest that future stratified aerial censuses would be best handled if they were conducted before 1000 or after 1300 hours.

The importance of the central Platte River Valley in Nebraska to migrant sandhill cranes has long been recognized. Because of this importance, numerous field investigations have dealt with population estimation, feeding ecology, habitat use, and the significance of the area in preparing cranes for continued migration and for reproductive performance.

Since 1957, the U.S. Fish and Wildlife Service has been actively involved in aerial and ground census of sandhill cranes. The 1st aerial surveys involved predawn counts of birds occupying the main roosting areas adjacent to the Platte River. Lewis (1978) believed that this approach was inadequate because population changes of ±25% over several years could not be detected. Because of the inadequacies involved with predawn counts of cranes, Ferguson et al. (1979) compared the effectiveness of stratified ocular and photographic counting methods. Their aerial survey differed from earlier attempts because birds were counted from mid-morning to mid-afternoon.

Results of the Ferguson et al. (1979) experiment, and subsequent counts made in 1980 (E. L. Ferguson, pers. comm.) suggest that more reliable estimates of sandhill crane populations along the Platte River are attainable with photographic techniques. Sandhill cranes during the day typically aggregate in huge flocks. Stratified photographic census is conducted when sandhill cranes are in these large flocks. Several biases can affect count totals because the birds are not randomly distributed; thus population estimates can vary considerably.

During the spring 1979 staging period, we conducted field work on characteristics of sandhill crane flocks along the Platte River. Our results provide information on diurnal periods when sandhill cranes form their largest flocks and have applicability to future aerial photographic censuses.

These data were gathered with the assistance of the several employees of the U.S. Fish and Wildlife Service in Jamestown, North Dakota, and Grand Island, Nebraska, and the Oklahoma Cooperative Wildlife Research Unit. J. Andrew and D. Johnson commented on an earlier draft of the manuscript.

STUDY AREA AND METHODS

The study area extended for 230 km along the Platte River between Grand Island and North Platte, Nebraska, and for 97 km along the North Platte River between North Platte and Lewellen, Nebraska. The study area was divided into 9 census units. The north-south boundaries of these areas approximated those of Ferguson et al. (1979). East-west boundaries were marked primarily by the location of river bridges (Fig. 1).

Field observations of sandhill cranes within each staging area were made during 5-26 March. These dates were selected to coordinate available manpower and to coincide with typical dates of peak sandhill crane numbers. Sandhill crane numbers were determined by a systematic ground search of each quarter section (64.8 ha) within each of the census areas.

Depending on crane densities and size of the census area, each of 14-16 observers was assigned a portion of the river valley in a staging area. Each census began at 0900 and typically ended by 1400, although some occasionally extended to 1600. The number of sandhill cranes on each quarter section in a census area was tabulated each date. The number and sizes of flocks, time of day, and habitat type associated with each flock were recorded. Data were tested for significance using the GLM procedure in SAS (SAS Institute 1979).

RESULTS AND DISCUSSION

Number of Sandhill Cranes

Counts of sandhill cranes in 1979 were restricted to areas within 11.2 km of the main river channel; the greatest use of lands by sandhill cranes occurred within 3.2 km of the river. Three census areas--Audubon South, North Platte, and Shelton South--supported 74.9% of the sandhill cranes during the peak of migration (Table 1). Simultaneous aerial photographic surveys (E. L. Ferguson, pers. comm.) also indicated that the largest numbers occurred in these areas.

The number of sandhill cranes observed differed significantly among areas (P = 0.0001), although they remained constant over time (P = 0.13). These data indicate that sandhill cranes do not leave the study area during the day; only movements within each area were observed. Thus, a complete count at any time should result in an accurate population estimate.

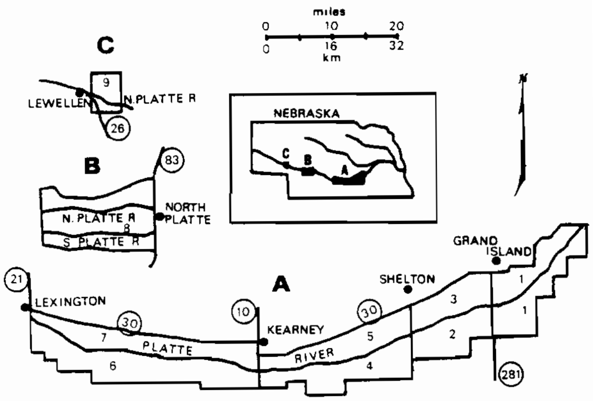

Fig. 1. Geographic location of sandhill crane count areas, Platte River Valley, Nebraska. Major highways, numbered and encircled, served as the E-W and N boundaries. Individual count areas are numbered and refer to those in text as: (1) Grand Island, (2) Shelton South, (3) Shelton North, (4) Audubon South, (5) Audubon North, (6) Overton South, (7) Overton North, (8) North Platte, and (9) Lewellen.

Number of Flocks

A flock of sandhill cranes was defined as any aggregation of birds that was spatially independent of other birds. Flock sizes ranged from single birds to 1 flock with 10,000 individuals observed at North Platte on 26 March (Table 2).

Data were collected on 1,665 sandhill crane flocks in 1979. The North Platte and Audubon South census areas supported 21.0% and 21.9% of the flocks observed (Table 3). The number of flocks differed significantly among areas (P = 0.001). The greatest number of flocks occurred during the period 0900-1100 hours (P = 0.05). The number of flocks decreased rapidly after this period, as indicated by the significantly different numbers between 1000-1100 and 1100-1200 hours (P = 0.05). The lowest number of flocks occurred during 1200-1300 hours.

Table 1. Numbers of sandhill cranes (and percentages of total weekly population) by individual staging area along the Platte River, Nebraska, 1979.

Staging area	March census date			
	5	12	20	26
Grand Island - Kearney				
Grand Island	110 (0.1)	805 (0.7)	16,340 (6.3)	13,612 (5.3)
Shelton North	0	618 (0.5)	6,422 (2.5)	17,120 (6.7)
Shelton South	10,099 (12.2)	11,516 (9.8)	38,562 (14.9)	42,581 (16.6)
Audubon North	19 (<0.1)	540 (0.5)	7,223 (2.8)	4,671 (1.8)
Audubon South	34,766 (42.0)	37,915 (32.4)	69,122 (26.8)	57,359 (22.3)
Overton - Elm Creek				
Overton North	0	8,175 (7.0)	6,623 (2.6)	11,110 (4.3)
Overton South	11,964 (14.5)	14,681 (12.6)	25,057 (9.7)	11,974 (4.7)
North Platte	25,105 (30.3	41,048 (35.1)	85,588 (33.2)	93,750 (36.5)
Lewellen	750 (0.9)	1,585 (1.4)	3,175 (1.2)	4,412 (1.7)
Totals	82,813	116,943	258,112	256,589

Table 2. Frequency distribution of sandhill crane flocks during 0900-1300 hours.

Flock size	Flocks	Percent total
1-50	276	26.9
51-100	137	13.3
101-199	125	12.2
200-499	237	23.1
500-750	76	7.4
751-999	39	3.8
1000-1999	100	9.7
2000-2999	21	2.0
3000-4999	9	0.9
5000-9999	6	0.6

Table 3. Number of sandhill crane flocks observed in each staging area by diurnal period.

	Time				
Staging area	0900	1000	1100	1200	1300
Grand Island	26	14	12	1	2
Shelton North	46	29	0	25	3
Shelton South	92	179	66	22	14
Audubon North	2	4	2	9	11
Audubon South	83	148	107	24	a
Overton North	35	125	20	19	a
Overton South	45	42	18	15	2
North Platte	78	72	66	47	84
Lewellen	a	a	33	23	10
Totals	407	613	224	185	126
% total	24.6	37.0	19.6	11.2	7.6

[a] No data available.

Mean Flock Size

Mean flock size was significantly different among areas (P = 0.039) as well as among time periods (P = 0.004). Between areas, Audubon South and Grand Island supported larger mean flock sizes than all the other areas (P = 0.05).

Our data vary considerably from that of Bliese (1976), because the highest flock frequency we observed was in the range of 1-50 and 200-500. Bliese noted that in the Gibbon to Overton region, about 77% of the flocks were made up of 50 or fewer birds and 84% had less than 100. We found that 26.9% of the flocks contained 50 or fewer birds and 40% had fewer than 100. This difference is probably related to observer variability and different considerations of what constitutes a flock, rather than actual changes in flock size or the number of flocks over several years.

Largest mean flock size occurred during 1200-1300 hours, and the lowest means occurred before 1000 (Table 4). During 1200-1300 hours, flock size was significantly different than at other times (P = 0.05). Flock sizes during other time periods were generally similar. Throughout the study area, flock size increased slowly through mid-morning, peaked at 1200 hours, and then declined sharply thereafter (Fig. 2).

Changes in diurnal flock size and the number of flocks per area are probably related to changes in feeding and social requirements during the day. Wheeler and Lewis (1972) reported that sandhill cranes leave primary roost sites along the river at sunrise and 1st occupy pastures and hayfields within 0.8 km of the roost. Fritzell et al. (1979) reported that use of cropland (primarily corn) was greatest during early morning and again in early evening. Sandhill crane movements during both periods probably correspond with use of corn to replenish energy reserves before and after roosting for the night.

Table 4. Mean sandhill crane flock size in a staging area by diurnal period.

	Time				
Staging area	0900	1000	1100	1200	1300
Grand Island	450	325	495	1000	184
Shelton North	70	130	a	297	478
Shelton South	200	200	336	1019	288
Audubon North	40	333	275	979	152
Audubon South	392	405	644	823	a
Overton North	72	97	278	224	a
Overton South	273	870	426	447	204
North Platte	100	398	474	464	520
Lewellen	a	a	57	73	124
Mean	177	309	332	592	217

[a] No data available.

Fritzell et al. (1979) reported that habitat use among radio-marked sandhill cranes included 68% use of cropland and 18% use of native grass (in this instance, primarily wet meadows). Reinecke and Krapu (1979) speculated that sandhill cranes occupied cornfields to replenish depleted energy reserves and then moved to native grasslands to obtain a protein source.

Miller and Stephen (1966) reported that spring migrant sandhill cranes at Last Mountain Lake, Saskatchewan, exhibited behavior similar to that which we observed in this study. Although they were working with a much smaller population of birds (N = 4,647), 93% of the

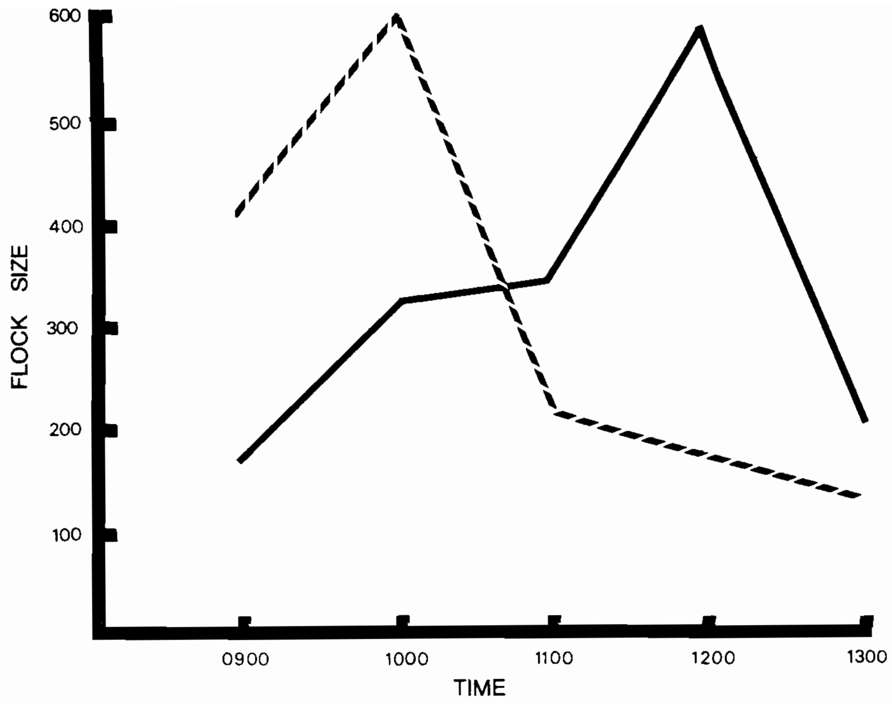

Fig. 2. Changes in mean flock size and the number of flocks of sandhill cranes. Mean flock size is shown with a solid line, the number of flocks is shown with a dashed line.

sandhill cranes they observed left their roost sites in flocks of <10, but later formed large feeding flocks. Madsen (1967), working with fall migrant sandhill cranes in North Dakota, similarly observed that the size of flocks leaving the roost was small, but at feeding sites cranes formed large flocks, particularly around 1200 hours.

Because formation of large flocks among sandhill cranes is apparently widespread and regular, it may signify more than a random occurrence. These aggregations are apparently commonplace in bird migration. Wynne-Edwards (1965) referred to such aggregation as epideictic phenomena which include "displays or special occasions which allow all the individuals taking part to sense or become conditioned by population pressure." If this is correct, then we suggest that the function of these aggregations of sandhill cranes may be social stimulation for initiating the next segment of migration. Large aggregations may also serve to further stimulate breeding adults for the nesting season. However, Madsen's (1967) observations of similar behavior during fall migration may tend to rule out that possibility.

MANAGEMENT IMPLICATIONS

The importance of the spring aerial sandhill crane census along the Platte River cannot be overstated. The Platte River Valley is the logical place to obtain the most accurate estimate of the total because virtually the entire Central Flyway population uses the area.

Our data suggest that, depending upon the census method to be used, there may be 2 optimal diurnal periods for conducting aerial sandhill crane censuses. The number of sandhill crane flocks was typically largest during 0900-1100 hours; consequently, the stratified aerial survey described by Ferguson et al. (1979) would probably be best conducted during those periods. Censusing of smaller flocks would yield a more precise estimate of the population by reducing the variance of the estimates. Hence, intensive censusing is suggested during periods of small flock size.

Stratified aerial surveys conducted during 1100-1300 may result in population estimates with reduced reliability because the number of flocks during the period is smaller, but mean flock size is significantly larger. With a greater degree of clumping of sandhill crane numbers during that period, the chance of recording smaller flocks decreases. Ferguson et al. (1979) reported that the probability of counting errors during ocular surveys increases significantly with increased flock size. However, some past surveys have been conducted to determine the largest number of birds in a given area during the shortest time period. In the latter situation, counting sandhill cranes during 1100-1300 hours would be most desirable.

Probably the most reliable surveys in the future could be made by using several aircraft simultaneously over the entire study area rather than the present situation where only 1 aircraft is used Ideally, future surveys would be conducted with 4 aircraft in 4 areas: Grand Island to Shelton Bridge; Shelton Bridge to Kearney; Kearney to Lexington; and North Platte to Sutherland. Several thousand sandhill cranes use the Clear Creek marshes east of Lewellen, and these should be censused more regularly in the future. These birds usually gather in large flocks directly adjacent to the North Platte River during the early afternoon (Faanes, in prep.). Because of this, an aerial survey could be conducted on the same day as the North Platte survey. Rather than a stratified sample, most of these birds at Lewellen could be counted by photographing the wet meadows along the river, and a reliable total count would probably be obtained.

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RELATION OF HYDROLOGIC AND GEOMORPHIC CHANGES TO WILDLIFE HABITAT IN PLATTE RIVER CHANNELS, SOUTH-CENTRAL NEBRASKA

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Abstract: Flow regime and channel morphology in the Platte River basin have changed significantly since about 1860. Channel widths of the Platte River in the 1970's at 6 locations between Cozad and Ashland, Nebraska, ranged from 9 to 92% of the 1860 widths. Regulation of flow by onstream dams and reservoirs, diversions of surface water, pumping of groundwater for irrigation, power generation, and other uses, have had significant effects on the hydrology of the basin. These changes also have had, through their effects on channel morphology, cumulative detrimental effects on the riverine habitat of sandhill cranes (*Grus canadensis*), whooping cranes (*G. americana*), and other migratory birds.

INTRODUCTION

The Platte River and its tributaries, the North Platte and South Platte rivers (Fig. 1), are typical of streams that originate along the Continental Divide in the Rocky Mountains and flow over the semiarid to subhumid Great Plains. Much of their flow is derived from spring snowmelt in the mountains. Most of the streamflow has been appropriated for irrigation of crops, for municipal and industrial use, and for generation of hydropower. The rivers have been an integral part of the economy of the region since the mid-19th century.

Migratory waterfowl also use the river and adjacent farmland in the Platte River Valley of central Nebraska during their annual migration stopover in March and April. An estimated 70 to 80% of the world's lesser and Canadian sandhill cranes (*G. c. canadensis* and *G. c. rowanii*) and a small number of whooping cranes use the river channel and adjacent agricultural land between Shelton and Grand Island, Nebraska, each year on their way to Canada, Alaska, and Siberia (Williams 1978).

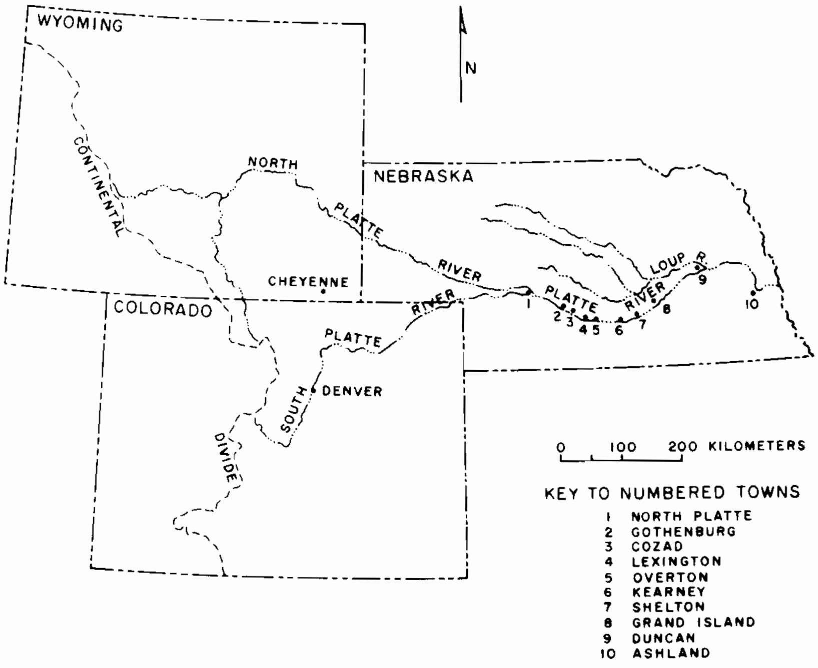

Fig. 1. Map of the Platte River basin, Colorado, Wyoming, and Nebraska.

Concern for the habitat of the sandhill cranes, whooping cranes, and other migratory birds prompted a study of the Platte River basin that included hydrologic regime, changes that have occurred in channels since settlement of the basin, and possible effects of these changes on waterfowl habitat. One of the objectives of the study by the U.S. Geological Survey, begun during 1979, was to investigate and document historical changes in channels and hydrology since 1860. The purpose of this paper is to summarize the results of that part of the study.

We thank the following members of the Upper Platte River Project who worked with us in collection of data and in preparation of interpretive reports: J. E. Kircher, M. R. Karlinger, K. D. Crowley, and A. V. Vecchia, Jr.

STUDY AREA

The South Platte and North Platte rivers originate in the Rocky Mountains of Colorado. After leaving the mountains, the rivers flow across the plains and form the Platte River at their confluence at North Platte, Nebraska (Fig. 1). The Platte River flows eastward through Nebraska to the eastern border of the state. The reach of the river that is considered to be critical waterfowl habitat by the U.S. Fish and Wildlife Service extends from Shelton to Grand Island, Nebraska, a distance of about 40 km.

HYDROLOGIC CHANGES

Water development within the Platte River basin has had a significant effect on both surface-water and groundwater hydrology. Use of surface water has changed the flow regime, and pumpage has caused groundwater levels to decline adjacent to some river reaches.

Large changes have been recorded in flood peaks, mean annual discharge, and low flows, as indicated by changes in the shape of flow-duration curves at some gaging stations. Peak flows on the North Platte River have been decreased by construction of dams (Williams 1978, Kircher and Karlinger 1981). Impoundment of flows in the South Platte River basin has been less extensive than in the North Platte River basin. As a result, peak flows of the South Platte River have not decreased significantly with time, except near North Platte, Nebraska (Kircher and Karlinger 1981). The recorded decreases that have occurred on the South Platte River are from surface-water diversions upstream from North Platte. Reduction of flood peaks on the North Platte River has caused the South Platte River flood peaks to become a more significant component of Platte River flood peaks. Peak flows of the Platte River near Overton, Nebraska, have decreased during the period of record (1914-80), but the decrease occurred before 1935. Hydrologic records for the Platte River near Grand Island, available only since 1935, show no significant change in flood peaks. A longer hydrologic record at Grand Island would be expected to show a decrease of flood peaks similar to that recorded near Overton.

Annual mean discharges of the North Platte River near North Platte, Nebraska (1895-1980), and of the Platte River near Overton, Nebraska (1914-80), have decreased during the period of record, probably as a result of impoundment of water by upstream reservoirs. Annual mean discharge near Grand Island has increased only slightly since 1935 although annual mean discharge upstream of Grand Island has changed significantly (Kircher and Karlinger 1981).

The shapes of flow-duration curves, plots of the probability distribution of mean daily flows at a gaged site, have changed with time for many gaging stations on the Platte River and its major tributaries (Eschner 1981, Kircher and Karlinger 1981). Slope of the flow-duration curve graphically represents variability of streamflow, and the position of the curve represents magnitude of streamflow. The curves for a given station, computed for short intervals of the period of record, show a reduction in short-duration flows; this reflects construction of dams. An increase in magnitude of long-duration flows has occurred because of temporal redistribution of flow by reservoir regulation, and return flow to the river, both as surface water and groundwater. These changes indicate that the flow of the Platte River is becoming less variable and has a greater baseflow component than it did before regulation by dams (Fig. 2).

The Platte River is in hydraulic connection with Quaternary sediments and with the Ogallala Formation of Tertiary age, which together comprise the principal aquifer in the Platte River valley (Lappala et al. 1979). The river acts as a control on the groundwater system and can affect groundwater levels.

Stage changes of the Platte River affect groundwater levels adjacent to the river. Water probably flows from the river to the aquifer at all river stages, but the rate of flow is greatest at high stages and least at low stages. The magnitude of stage change, the distance from the river, and the hydraulic properties of the aquifer all affect the magnitude and rate of changes in groundwater levels. Changes in the rate of evapotranspiration partly offset the effects of river-stage

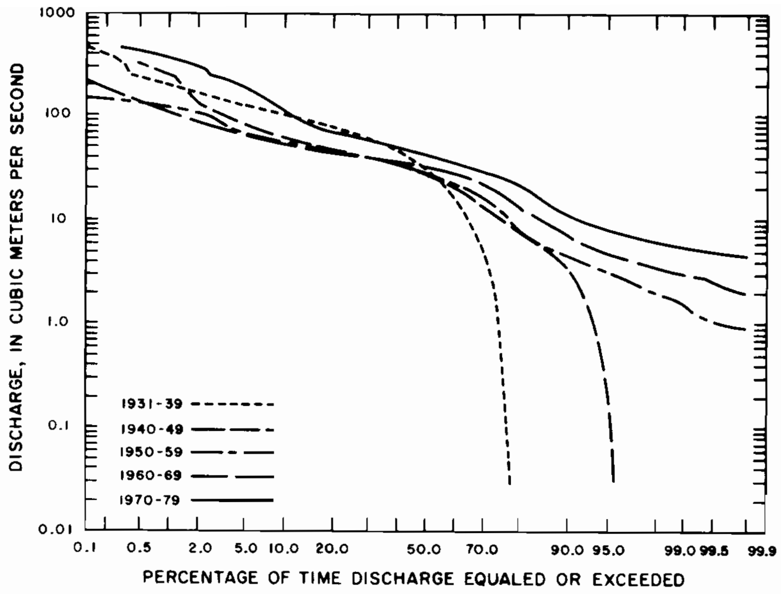

Fig. 2. Selected flow-duration curves, Platte River near Overton, Nebraska (water years 1931-79) (after Kircher and Karlinger 1981).

variation. As groundwater levels rise, evapotranspiration increases, whereas evapotranspiration decreases when groundwater levels decline.

Groundwater pumpage affects both surface-water and groundwater levels, but the relationship between pumpage and changes in water levels is complex. Drawdown caused by pumpage can cause enhanced flow from the river into the aquifer, resulting in decreased river stage. Return flows from recharge of applied irrigation water have contributed to the reduction of days of no flow and increased the magnitude of long-duration discharges. Pumpage causes groundwater levels to decline; however, this decline may result from a change in water-table gradient locally rather than from appreciable loss of storage regionally.

Changes in groundwater level have not been uniform throughout the Platte River basin. Net rises in the elevation of the water table have resulted from seepage of water from canals and reservoirs. Net lowering of the water table has resulted from groundwater pumpage.

MORPHOLOGIC CHANGES

Morphologic changes of the Platte River were documented by measuring channel width at specific locations on a General Land Office (GLO) map made about 1860, and on 6 sets of aerial photographs taken during the period 1938-79. Width of the Platte River channel generally has decreased with time (Table 1). The percentage of the channel, measured from GLO maps, that was occupied by the river at various times is shown in Fig. 3 for 6 river reaches. It is apparent that the rate of channel narrowing decreases in a downstream direction. This decrease probably is due to less irrigation development in the eastern part of the basin. The Platte River near Ashland, downstream from the confluence with the Loup River which has not had major hydrologic change, has shown very little change in channel width.

The rate of width reduction has varied with time. Before 1938, when the 1st aerial photographs were taken, the rate of channel-width reduction was relatively slow. The channel width narrowed rapidly from 1938 until about 1955. Since the mid-1950's, the channel-width reduction generally has been minimal. Channel widths in the 1970's, compared with 1860 widths, ranged from 9% near Cozad to 92% near Ashland (Fig. 3).

Decrease in channel width had occurred by 1938, but it is difficult to determine when the decreases began. A 1902 station description from a U.S. Geological Survey gage located near Lexington, Nebraska, indicates that the channel width was the same as it was in 1865. Thus, in south-

Table 1. Channel widths (m) of the Platte River, Nebraska, at selected locations in a downstream order.

Year	Cozad	Overton	Kearney	Grand Island	Duncan	Ashland
1860	1,161	1,545	1,484	1,100[a]	826	594
1938	1,015	890	1,298	704	--	--
1941	--	--	--	--	600	515
1949	--	--	--	--	--	539
1950	--	--	--	643	543	--
1951	204	451	698	--	--	--
1955	--	--	--	--	--	521
1957	113	460	695	664	521	--
1959	--	--	--	--	--	533
1963	110	408	308	530	--	--
1964	--	--	--	--	448	--
1965	--	--	--	--	--	530
1969	113	387	293	472	--	--
1970	--	--	--	--	424	--
1971	--	--	--	--	--	549
1978	--	--	--	--	411	--
1979	110	405	247	387	--	--

[a] Channel width from Grand Island, Nebraska, 30-foot topographic quadrangle, 1898.

central Nebraska, morphologic change of the Platte River apparently began sometime between 1902 and 1938.

CAUSES OF HYDROLOGIC CHANGES

The major causes for hydrologic changes in the Platte River basin probably are: (1) Climatic change, and (2) development of surface water and groundwater for a variety of uses. An analysis of precipitation statistics for Gothenburg, Kearney, and Grand Island, Nebraska, for 1939-78 shows large standard deviations among months but no trend indicating climatic change (Vecchia 1981). Therefore, we assume that most of the streamflow changes are attributable to water development or to changes in precipitation before 1939.

Water resources of the Platte River basin have been extensively developed. Irrigation began in the middle to late 1800's and developed slowly until the end of the 19th century. These early irrigation developments consisted of surface-water diversions; construction of large onstream reservoirs began about 1900. Groundwater for irrigation came into popular use during the 1930's; however, in the early 1980's, groundwater withdrawals for irrigation far exceeded those of the earlier period. Municipal use of water also is increasing, but it is only a small component of the development within the basin. All of these developments have had significant effects on the hydrology of the Platte River basin.

CAUSES OF CHANNEL MORPHOLOGY CHANGES

Changes in streamflow and sediment transport attributable to water development have been largely responsible for changes in channel morphology. Basically, the processes involved are an

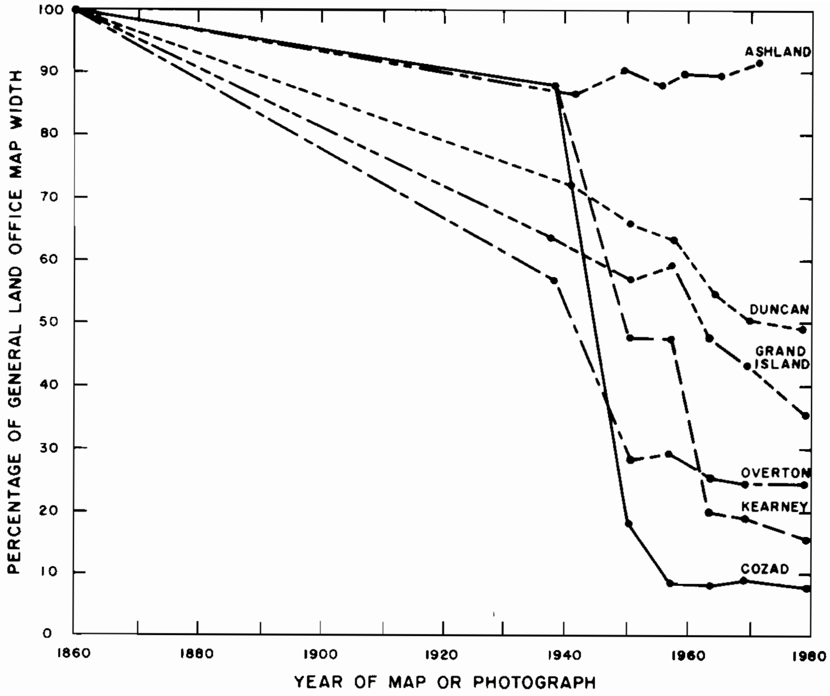

Fig. 3. Percentage of channel width, measured from General Land Office maps, occupied by the Platte River at 6 locations in Nebraska.

enhanced formation of islands and their subsequent attachment to the banks and floodplain, or to other islands.

The channel during the 1860's generally was broad and open. By 1938, width had decreased at most locations upstream from Grand Island with the formation of islands. The banks also had shifted toward the center of the channel as a result of the formation of islands and their attachment to the floodplain. Island attachment resulted from channel abandonment rather than from migration of the river course. Bars within the river were noted by members of the Long Expedition in 1820 (James 1823), but these bars were not preserved as islands. Hydrologic changes, which began with irrigation development and were accelerated by construction of large dams, included a decrease in flood peaks and fewer days of no flow. Reduction in flood peaks allowed establishment of vegetation on sandbars by reducing the scour potential. Longer periods of low flow probably provided more favorable conditions for seed germination. One, or both, of these effects increased the preservation of vegetated islands.

EFFECTS OF HYDROLOGIC CHANGES ON RIVERINE HABITAT

Changes in channel geometry resulting from changes in water-discharge and sediment-transport characteristics have had a marked effect on the waterfowl habitat along the Platte River in central Nebraska. Hydrologic processes that control the riverine environment need to be understood if habitat is to be maintained and managed effectively in the future. Some of the questions that need to be answered in order to predict future habitat conditions will be discussed briefly.

Wildlife managers have determined the minimum open-channel width required for roosting sandhill cranes is approximately 150 m, and the minimum flow depth across submerged sandbars is approximately 0.6 m (C. Frith, U.S. Fish and Wildlife Service, pers. comm., 1981). These conditions exist at many locations in the reach of the Platte River between Shelton and Grand Island, Nebraska, when cranes are there during March and April. Additional hydrologic studies need to be conducted to determine if the flow regime in the 1980's will maintain the channel geometry without any further encroachment by vegetation.

Another aspect of the environment that is vital to waterfowl habitat is the preservation of wet meadows where migratory birds feed on invertebrates. Observations indicate that groundwater levels in wet meadows respond directly to changes in river stage. Any lowering of river stage, even short-term, will affect the subirrigation of these meadows. Field studies need to be conducted to determine the effects of fluctuations in groundwater levels on invertebrate populations.

Water-resources development has had a marked effect on flow regime and channel morphology in the Platte River and its major tributaries during the past 100 years. There are still many unanswered questions, however, about long-term effects of these changes on the riverine habitat of migratory birds.

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WHOOPING CRANE USE OF THE PLATTE RIVER, NEBRASKA--HISTORY, STATUS, AND MANAGEMENT RECOMMENDATIONS

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Abstract: Whooping crane (*Grus americana*) use of the Platte River in Nebraska was investigated as part of a study of whooping crane migration conducted by the Department of Wildlife Ecology, University of Wisconsin-Madison. This paper summarizes the results of that investigation. Analysis of historical and recent sightings indicates that use of the river has probably declined during the past 30 or more years. This may be due to deterioration of riverine roost habitat quality and increased human activity near the river. The present-day Platte River is probably a nontraditional stopover area for migrating whooping cranes because it still affords suitable habitat along a portion of its length within the cranes' primary migration corridor but is used infrequently. Deterioration and loss of other potential stopover areas in the region underscores the need to preserve habitat along the Platte River to provide roost site options for whooping cranes in south-central Nebraska. A management plan for whooping cranes in the Platte River Valley must be based on knowledge of the cranes' migration corridor, chronology of migration, general migratory behavior, food habits, feeding habitat, roosting habitat, roosting behavior, and disease susceptibility. The key to managing whooping cranes along the Platte is habitat acquisition and maintenance. Top priority for acquisition should be given to riverine habitat for roosting in association with extensive, nearby "wet meadows" and native grasslands for feeding. Additional management efforts include monitoring habitat quality and whooping crane use of the river and Rainwater Basin area. Studies of whooping crane habitat use and behavior in the Platte River Valley and avian cholera studies in the Rainwater Basin area should be the primary research priorities.

Each spring and fall virtually all of the midcontinent population of endangered whooping cranes cross the Platte River in Nebraska on migration between their nesting grounds in northern Canada and wintering grounds on the Gulf Coast of Texas. Whooping cranes have been sighted on the Platte River many times since European settlers 1st entered the region. Thus, biologists who 1st studied the whooping crane concluded that the river was a major stopping place for the migrants (Swenk 1933, Allen 1952:94) and proposed that a portion of the river be protected as a refuge for the resting birds. In later years, it was suggested that whooping cranes "stage" on the Platte in the spring in much the same way that sandhill cranes (*Grus canadensis*) do today (Lewis 1974:96 citing Swenk 1933; Logan et al. 1976 citing Swenk 1933, Allen 1952, and Hill 1975, as the basis for their statements), lending further support to proposals for a refuge. At the time these proposals were made, however, the overall significance of the Platte River to whooping cranes was not thoroughly understood; thus, the proposals lacked the necessary supporting biological data to justify their implementation.

In recent years, significant changes in the physical character of the Platte River (Frith 1974, Williams 1978, Currier 1981), an apparent decrease in its use by whooping cranes, and changing use patterns of sandhill cranes have been viewed with alarm by many conservation groups and public agencies (Logan et al. 1976, Wallenstrom 1976, Kroonemeyer 1979). They have raised the question of what will happen to the remaining sandhill cranes and whooping cranes if the Platte River is degraded to such an extent that it no longer offers suitable habitat. In response to this concern the U.S. Fish and Wildlife Service, in April 1974, proposed the establishment of a 6,070-ha National Wildlife Refuge on the Platte (Wallenstrom 1976). The proposal was later withdrawn because of severe landowner opposition.

The Whooping Crane Recovery Team also acknowledged this concern about habitat deterioration along the Platte River and listed the Platte as 1 of its "areas of concern" in their Whooping Crane Recovery Plan (USFWS 1980). The Recovery Team realized there were insufficient data to make ecologically sound decisions regarding "critical habitat" (see Federal Register, 15 May 1978 for a definition) for migrating whooping cranes so they included in their Recovery Plan a recommendation for migration studies. Subsequently, an 87-km (54-mile) stretch of the river from Lexington to Shelton,

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[1] Much of this paper was prepared in conjunction with the Platte River Ecology Study while the author was employed by the U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, North Dakota 58401. The author's present address is Department of Biology and Ecology Center, UMC 53, Utah State University, Logan, Utah 84322. Views expressed by the author do not necessarily represent those of the U.S. Fish and Wildlife Service.

Nebraska, was designated "critical habitat" by the Secretary of the Interior (Federal Register, 15 May 1978) so that it would not be lost to development before its overall significance to whooping cranes could be determined.

In April 1978 the Office of Endangered Species, U.S. Fish and Wildlife Service, contracted with Dr. S. A. Temple, Department of Wildlife Ecology, University of Wisconsin-Madison, to study whooping crane migration. Objectives of the study were to

1. Supplement and analyze the existing catalog of information on whooping crane flight lines and stopovers within the U.S.;
2. Describe the roost sites used by migrating whooping cranes in terms of a general habitat classification scheme and collect data on roost site characteristics of particular importance to cranes;
3. Docment the feeding habitats, food habits, general behavior, and migration dynamics of migrating whooping cranes; and
4. Synthesize the above information to provide an ecologically sound basis for decisions on "critical habitat" for migrating whooping cranes.

Field work was conducted from June 1978 through June 1979 (Johnson and Temple 1980). This paper presents the results and conclusions of the study pertaining to whooping crane use of the Platte River and nearby areas. The results and conclusions presented here are limited by small sample sizes and the nature of the data (i.e., many of the data were collected through interviews of inexperienced crane observers, and, thus, have been selectively filtered by untrained eyes and the passage of time). These limitations necessarily render this a preliminary report.

Drafts of the manuscript have been critically reviewed by Stanley A. Temple, Scott Melvin, Ross Lock, Gary Krapu, Chuck Frith, James Lewis, John VanDerwalker, George Archibald, Roderick Drewien, Michael Sutton, and Ron Windingstad. Their comments, suggestions, and corrections have been extremely helpful.

HISTORY AND STATUS OF WHOOPING CRANES AND THE PLATTE RIVER

Past History

Reports of whooping cranes in the Platte River region came soon after the arrival of European settlers. Thomas Say, arriving at Fort Calhoun, Washington County, Nebraska, on 19 March 1920, observed that "great flights of geese, swans, ducks, brant, and cranes have been passing up the (Missouri) river." (Allen 1952). Swenk (1933) believed that the cranes Thomas Say referred to were whooping cranes even though the observation date was almost 2 weeks before the normal initiation of whooping crane migration through Nebraska. Allen (1952) thought that the "great flights" were sandhill cranes perhaps accompanied by an occasional whooping crane.

M. Swenk (1933) was the 1st biologist to study whooping cranes in Nebraska; his efforts were concentrated in the "Big Bend" region of the Platte River. He compiled sightings dating to the 1880's and recorded 93 sightings (involving 998 individual cranes) in Nebraska during the period 1912-1933. Not surprisingly, most of the sightings were from the "Big Bend." The authenticity of many of the sightings was subsequently questioned by Allen (1952).

Swenk (1933) was 1st to suggest that the Platte River was a major stopping place for migrating whooping cranes. He based his conclusion on 4 lines of evidence: (1) the large number of sightings from the Platte River; (2) the lack of sightings from other areas along the migration route; (3) discussions with old-time hunters who told him that large flocks of whooping cranes commonly stopped on the Platte each spring and fall; and (4) his "knowledge" that the cranes had an "ancestral habit" of making a mid-migration stop in the Platte region to rest and feed. Swenk did not explain how he learned of the cranes' "ancestral habits," and he knew little about the migration of whooping cranes outside the Platte River Valley except for a very fragmentary picture he was able to gain from the literature. Consequently, his conclusion was premature.

A. M. Brooking of the Hastings Museum compiled the Nebraska records for 1934-1944; his efforts were also concentrated in the Platte River Valley. He published several lists of observations and a brief status report on the species (Brooking 1934, 1943a, 1943b, 1944).

In the late 1940's R. P. Allen of the National Audubon Society embarked on a long-term study of the whooping crane which culminated in 1952 in the publication of his classic monograph *The Whooping Crane.* Allen collected firsthand observations and thoroughly reassessed the sightings reported by Swenk and Brooking; from these he developed a list which he felt represented valid sightings in Nebraska for the period 1820-1948. Allen eliminated many sightings reported by Swenk and Brooking because they simply involved too many cranes for the date. His final list totalled 123 sightings, of which 87 occurred in counties along the Platte River. Allen also believed that the Platte was a major stopping place for whooping cranes on the basis of the same criteria listed

Table 1. Confirmed sightings of whooping cranes on the Platte River, 1950-Spring 1981 (Johnson and Temple 1980, USFWS 1975-81, USFWS 1980).

Date	Location	Number of birds[a]
4 May 1950	Near the Platte River at Overton (Dawson Co.)	1U
20-21 October 1966	9.6 km (6 mi) NE of Phillips (Hamilton Co.)[b]	3A, 2J
31 October to 1 November 1974	3.2 km (2 mi) E of Minden I-80 interchange (Buffalo Co.)[b]	2A
20 April 1975	0.8 km (0.5 mi) E of Odessa bridge on Platte River (Phelps Co.)	5A
29 March 1977	3.2 km (2 mi) E of Highway 10 bridge on Platte River (Buffalo Co.)	1A
17 and 18 April 1980	1.6 km (1 mi) E of Minden I-80 interchange and within National Audubon Society refuge (Buffalo Co.)[b]	2A
19 April 1980	Flying along river south of Kearney (Buffalo Co.)	7A

[a] U = birds of unknown age, A = adult, J = juvenile.

[b] Birds observed *on* the Platte River.

by Swenk (Allen 1952:94). However, at the end of his study there still remained a fragmentary picture of whooping crane migration outside the Platte River Valley.

Recent History

From 1950 through spring 1981 there were 7 "confirmed" (see Whooping Crane Recovery Plan for definition) sightings of whooping cranes on or near the Platte River (Table 1). The sightings were all between Overton and Chapman, and 6 were within the area designated "critical habitat." Five sightings were made in spring and 2 in fall. Details of most of these sightings are discussed elsewhere (USFWS 1981).

Trends in Use of the Platte River by Whooping Cranes

There has been a significant decrease in the number of whooping crane sightings on the Platte River in recent years. During the period 1890 through 1919 there were 17 sightings on or near the river (Allen 1952). From 1920 through 1949 there were 65 sightings (Allen 1952), but from 1950 through spring 1981 there were only 7. Although some of Allen's sightings would not be classified "confirmed" according to the Recovery Team's definition, a downward trend is still evident. Possible causes for this decline include (1) a change in the population of whooping cranes, (2) a decrease in the amount of effort to observe and report cranes on the river, (3) reduced visibility of cranes on the river due to encroachment of woody vegetation, and (4) an actual decrease in use of the river by whooping cranes.

Changes in the size of the whooping crane population could not have accounted for the decrease in sightings. The total population of migratory whooping cranes declined steadily from 1890 through 1941, yet there was an increase in sightings along the Platte River during that period. From 1942 through 1981 the population increased nearly 5-fold (USFWS 1980), yet the number of sightings fell markedly.

It is difficult to assess whether or not there has been a decrease in efforts to observe and report whooping cranes along the Platte River in recent years, because a number of unquantified variables are involved. While Swenk, Brooking, and Allen were actively soliciting firsthand observations from 1912 through 1948, the number of reports increased through the years, indicating growing public awareness of the efforts of these biologists. Although biologists have not been actively soliciting observations in the past several years (the last 5 years may be an exception), increasing numbers of active bird watchers in the Platte River Valley may have filled this void (G. Krapu pers. comm.). Personnel of the Nebraska Game and Parks Commission and the U.S. Fish and Wildlife Service, university researchers, and private refuge managers also have been monitoring crane activity in recent years. In contrast, some landowners may have become more reluctant to report sightings in fear of a federal land takeover for a refuge (R. Lock pers. comm.).

Encroachment by woody vegetation has significantly reduced visibility of the river channel in many areas. This has been only partially offset by improved access to agricultural fields bordering the river and increased crane watching activity. Therefore, it seems possible that whooping cranes now have somewhat less chance of being detected and reported than they did in years past. The decrease in visibility remains unquantified but is probably small.

Available evidence suggests there probably has been an actual decrease in use of the Platte River during the last 30 or more years. Although the reasons for the decline are not totally clear, it appears that changing habitat conditions on the river and increased human activity near the river may have been responsible.

During the last 50 or more years there has been a significant reduction of river flows (Williams 1978) which has led, in some areas, to a reduction of river width, an increase in the amount and density of woody vegetation on the banks, and stabilized and vegetated sandbars in mid-channel (Frith 1974, Currier 1981, USFWS 1981). Many stretches of the river which formerly offered good habitat for roosting and loafing have apparently become marginal or unsuitable for use by whooping cranes.

Human disturbance factors have included the construction and use of Interstate 80 immediately north of the Platte River, general road traffic near the river, farming activities in areas which formerly were part of the river channel, gravel pit operations, home construction near the river, and wildlife observers and researchers. These activities have probably inhibited cranes from using portions of the river at certain times.

THE SIGNIFICANCE OF THE PLATTE RIVER TO WHOOPING CRANES

The importance of the Platte River to whooping cranes has been the subject of much discussion in recent years as pressures have increased to divert river flows for other uses. Additional diversions will undoubtedly result in further habitat deterioration, thus concern has been expressed over the welfare of the whooping crane population. Conservationists must know how whoopers presently use the Platte before they can determine how whooping cranes may be affected by loss of the river. (Discussions of how the cranes used the river in years before their numbers were so drastically reduced are not appropriate here except as speculation on how the cranes may use the river in the future when their numbers have increased substantially.) Specifically, the wildlife manager must know if migrating whooping cranes use the Platte River as a staging area, a traditional stopover area, or a nontraditional stopover area.

A staging area is a site where cranes gather during the 1st segment of their fall migration. Staging areas occur relatively close to the breeding grounds (within the 1st 20% of the migration route) and are often used every year (Melvin and Temple--this proceedings). Cranes derive 2 primary benefits from gathering at staging areas--the opportunity to ready themselves physiologically (by replenishing or adding to their lipid reserves) for the next stage of migration (Pitelka 1979) and social interaction which facilitates learning of the migration route (Melvin and Temple--this proceedings).

A traditional stopover area is located farther along the migration route (from 30 to 70% of the distance from the breeding grounds, see Melvin and Temple--this proceedings), is usually used for an extended period, and is used from year to year (Bellrose and Crompton 1970, Bellrose 1976). A nontraditional stopover area offers suitable habitat but is used on an infrequent basis and only when it is encountered by birds looking for a place to stop (Johnson and Temple 1980). It is used opportunistically and usually for short periods of time (overnight or 2-day stops, Melvin and Temple--this proceedings).

Further deterioration or total loss of the Platte River will have different consequences for whooping cranes depending on the manner in which they use the river. If the river serves as a staging area, its loss could have drastic consequences for migrating whooping cranes by denying them the opportunity to replenish necessary lipid reserves or interact socially. If it is used as a traditional stopover area, its loss could also be significant by adversely affecting the survival ability of cranes needing to rest and feed there. However, if the river is used only as a nontraditional stopover area, its loss may be insignificant, depending upon the availability of other suitable stopover areas in the vicinity.

It is obvious that whooping cranes do not use the Platte as a staging area because the river does not occur within the 1st 20% of the fall migration route. There is also little evidence to suggest that cranes use the river as a traditional stopover area. Whooping cranes migrate as individuals, pairs, family groups, and small flocks; they are not known to congregate into large flocks in a limited geographic area as are sandhill cranes (Frith 1974). There is no solid evidence to indicate that individuals, pairs, families, or small flocks presently use the same area on the river from year to year. Whooping cranes rarely stay on the Platte River for longer than 5-7 days (Allen 1952), with overnight or 2-day stops being most common (Johnson and Temple 1980). This time interval would most likely be an insufficient period of time for them to replenish lipid reserves.

The present-day Platte River is probably a *nontraditional stopover area* for whooping cranes. All migrating whoopers of the Aransas-Wood Buffalo population must cross the river because it forms an east-west transect of their migration corridor; some cranes settle and rest there because it still offers suitable habitat along a portion of its length. The whooping cranes could probably adjust to the loss of the Platte River without negative consequences if a sufficient number of other suitable stopover areas are available in the immediate vicinity. However, other suitable stopover areas in the region are being lost at a very rapid rate, especially in the Rainwater Basin area where over 85% of the former wetlands have been drained for agricultural use (Nebraska Game and Parks Commission 1972; over 92% have been drained as of 1981 according to C. Frith pers. comm.). As stopover options decline, remaining wetlands assume increasing importance to whooping cranes. Maintenance of those stretches of the Platte River which still offer suitable habitat (and perhaps reclamation of some degraded stretches) will help insure that the roosting needs of whooping cranes are met in south-central Nebraska even if many of the remaining lentic wetlands are drained.

Heavy whooping crane use of wetlands in the Rainwater Basin area should be viewed with alarm because major outbreaks of avian cholera have occurred in many of the wetlands utilized by whooping cranes (Table 2). These outbreaks are quite likely to increase in frequency and intensity (USFWS 1981) with the continued loss of wetlands and further crowding of waterfowl and crane populations into those remaining wetlands. Whooping crane use of wetlands in the Rainwater Basin area may constitute a direct threat to their survival because sandhill cranes and presumably whooping cranes are susceptible to avian cholera (J. Hurt and R. Windingstad pers. comm.). Twice in the last 6 years (spring 1975 and spring 1979) whooping cranes have been "hazed" out of wetlands experiencing cholera outbreaks (J. Hurt and R. Windingstad pers. comm.); on 1 of these occasions (spring 1975) the cranes resettled on the Platte River. These incidences underscore the need to preserve stretches of the Platte as refuges to which whooping cranes can be "hazed" to minimize their exposure to avian cholera. In summary, the most important role of the Platte River appears to be in providing suitable roost habitat in an environment with low potential for disease outbreaks.

MIGRATION DYNAMICS AND HABITAT REQUIREMENTS OF WHOOPING CRANES IN THE PLATTE RIVER VALLEY

A sound management strategy for any species must be based on a thorough knowledge of that species' behavior and ecology. For whooping cranes in the Platte River Valley, management must be based on knowledge of the cranes' migration corridor, chronology of migration, general migratory behavior, food habits, feeding habitat, roosting habitat, roosting behavior, and disease susceptibility. This section presents a brief summary of current knowledge of these attributes.

Migration Corridor

The whooping crane's primary migration corridor (see Johnson and Temple 1980 for a definition) through Nebraska averages 160-192 km (100-120 miles) wide and angles approximately 15° west of north. The eastern edge of the corridor intersects the northern border of the state at 98°45' longitude and the southern border at 98°15' longitude. The western corridor edge intersects the northern state border at 101°00' longitude and the southern border at 10030' longitude. Eighty-two percent of all confirmed, post-1949 sightings have been made within the primary corridor; the remaining sightings have been predominantly to the west (Johnson and Temple 1980). The primary corridor includes a stretch of the Platte River from near North Platte to just east of Grand Island, and much of the Rainwater Basin area (Fig. 1).

Table 2. Confirmed sightings of whooping cranes in the Rainwater Basin area, 1950-Spring 1981 (Johnson and Temple 1980, USFWS 1975-81, USFWS 1980).

Date	Location	Number of birds
Spring		
10 April 1969	6.4 km (4 mi) S and 6.4 km (4 mi) W of Minden (Kearney Co.) SE¼, Sec. 19, T6N, R15W[a]	1A[b]
8 April 1970	6.4 km (4 mi) S of Upland (Franklin Co.)	2A
11 April 1973	5.6 km (3.5 mi) S and 2.4 km (1.5 mi) E of Upland (Franklin Co.) Sec. 35 or 36, T4N, R14W	2A
17-19 April 1975	Funk Lagoon, 4.8 km (3 mi) N and 2.4 km (1.5 mi) E of Funk (Phelps Co.) Sec. 2, T6N, R17W[a]	9A
8-9 April 1979	Moses Hill wetland, 6.4 km (4 mi) NNW of Holdrege (Phelps Co.) Sec. 3, T6N, R19W[a]	4A
2 April 1980	8.0 km (5 mi) S and 3.2 km (2 mi) W of Minden (Kearney Co.)(near NE Sacramento Basin State Area) NW¼, Sec. 11, T5N, R15W[c]	2A
7-8 April 1980	South Funk wetland, 2.4 km (1.5 mi) N and 0.8 km (0.5 mi) E of Funk (Phelps Co.) SE¼, Sec. 16, T6N, R17W[c]	7A
Fall		
17 October 1960	SE Sacramento State Mgmt. Area 2.4 km (1.5 mi) S and 3.2 km (2 mi) W of Wilcox (Harlan Co.) Sec. 2 and 3, T4N, R17W[a]	2A, 1J
11 October 1967	Peterson WPA, 4.8 km (3 mi) S of Bertrand (Gosper Co.) probably Sec. 13, T6N, R21W[a]	2U
26 October - 10 November 1971	Bluestem Marsh, 1.6 km (1 mi) S and 6.4 km (4 mi) E of Axtell (Kearney Co.), SE¼, Sec. 19, T6N, R15W[a]	2A, 1J
19 October 1973	2.4 km (1.5 mi) S and 1.6 km (1 mi) E of Kenesaw (Adams Co.) Sec. 2, T17N, R12W[c]	3A
25 October 1974	Funk Lagoon, 4.8 km (3 mi) N and 2.4 km (1.5 mi) E of Funk (Phelps Co.) Sec. 2, T6N, R17W[a]	2A

[a] Wetlands in the Rainwater Basin area known to have had avian cholera outbreaks.

[b] A = Adult, J = juvenile, U = unidentified.

[c] Wetlands in the Rainwater Basin area in close proximity to avian cholera outbreak areas.

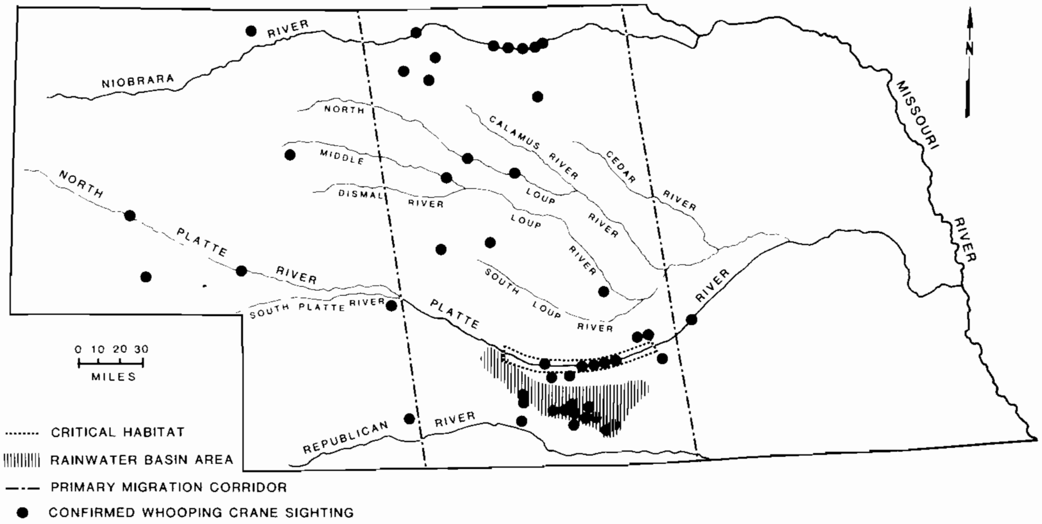

Fig. 1. Primary migration corridor and "confirmed" sightings (1950-Spring 1981) of whooping cranes in Nebraska (Johnson and Temple 1980, USFWS 1975-81, USFWS 1980).

Chronology of Migration

The chronology of spring and fall migration through Nebraska was documented by Allen (1952); data from the years 1950 through 1981 confirm the general pattern. Spring migration proceeds rapidly. The majority of cranes are observed between 1 April and 20 April; extreme dates have been 10 March and 15 May. From 1950 through 1981 cranes were seen in Nebraska from 3 April through 4 May. Juveniles returning north with their parents have been observed from 14-19 April.

During fall migration, most cranes are seen from 10 October through 1 November, with extreme dates being 22 September and 14 November. From 1950 through 1980 cranes were observed from 3 October through 10 November. The 1st migrants to reach Nebraska each fall are usually individuals, pairs without young, or small groups of nonbreeders. Family groups begin to arrive around 16 October and sightings peak during 22-27 October. Families have been seen as late as 10 November. From 1950 through spring 1981 there were 7 sightings of whooping cranes on or near the Platte River; 5 were in spring and 2 in fall. Spring dates were 4 May 1950, 20 April 1975, 29 March 1977, 17-18 April 1980, and 19 April 1980. Fall dates were 21-22 October 1966 and 31 October - 1 November 1974.

General Migratory Behavior

Whooping cranes currently migrate as individuals, pairs, family groups, and small flocks. They are often observed in the company of sandhill cranes, usually as individuals. Whooping cranes are probably primarily diurnal migrants (Johnson and Temple 1980). They depart on migration in the morning, between 1st light and mid-morning, and stop at a wetland between late afternoon and last light to roost for the night. They may remain at a stopover for a single night or for up to several weeks; overnight and 2-day stops appear to be most common (Johnson and Temple 1980).

Food Habits

Little has been documented about the specific food items eaten by migrating whooping cranes, but it is known that they utilize both plant and animal material. Plant foods have included shoots of emerging winter wheat, waste milo in cow droppings, and waste milo, barley, wheat, and corn on the ground (Johnson and Temple 1980). Animal items have included egg masses of frogs and toads, beetles, small fish, frogs, crayfish, and snakes (Johnson and Temple 1980). Available evidence suggests that whooping cranes are omnivorous and opportunistic feeders during migration.

Feeding Habitat

Whooping cranes have been observed foraging in a wide variety of habitats. Fourteen upland and 10 wetland habitat types were represented among the 120 feeding sites documented by Johnson and Temple (1980). Eighty-four percent of the sites were in upland habitats and 80% of those involved agricultural lands. Fields containing emerging small grains or small grain stubble were the predominant agricultural types used. Utilization of wetland habitats for foraging was generally associated with sites in the immediate vicinity of evening roosts.

Feeding sites in upland habitats were usually characterized by excellent horizontal visibility (usually an unobstructed view in all directions for at least 91 m [100 yards] and often for several hundred meters, although in some circumstances visibility was limited to less than 91 m in a small portion of the field of vision), a lack of tall trees and dense shrubbery immediately around the site, short vegetation (often less than 30 cm [12 inches] high) on the site, limited topographic relief (usually less than 9-12 m [30-40 feet] and often less than 1.5-3.0 m [5-10 feet]), and gradual slopes (usually less than 7-9° and often less than 4-5°)(Johnson and Temple 1980).

Feeding sites in wetland habitats were usually characterized by water less than 0.4-0.6 m (1.5-2.0 feet) deep, excellent horizontal and overhead visibility, and either very short or very sparse emergent vegetation (Johnson and Temple 1980).

Roosting Habitat

Johnson and Temple (1980) documented 13 different types used for roosting by migrant whooping cranes; all involved surface water in some form. Both flowing and standing bodies of water have been used, and artificial as well as natural wetlands are represented.

Shallow river channels like those of the Platte River are 1 type of roost habitat used by whooping cranes. An evaluation of 10 documented river roosts identified the following characteristics as usually present (Johnson and Temple 1980).

1. Wide channel - 9 of the 10 sites were between 155 and at least 365 m (170 to at least 400 yards) wide.

2. Slow flow - a flow rate of approximately 0.4-1.8 mps (1-4 mph) at the roost site, although water in the main channel may be flowing much faster.

3. Shallow water - all sites were less than 30 cm (12 inches) deep and 6 of 9 sites were 5-15 cm (2-6 inches) deep. Water in the main channel may be considerably deeper.

4. Unvegetated.

5. Fine substrate, usually sand.

6. Good horizontal visibility, usually an unobstructed view from riverbank to riverbank and at least a couple of hundred meters upstream and downstream (or to a bend in the river). In some situations visibility is limited to less than the above distances within a small portion of the field of vision.

7. Good overhead visibility. No tall trees, tall or dense shrubbery, or high banks in the immediate vicinity of the roost.

8. Close proximity to a suitable feeding site, usually less than 1.6 km (1 mile). In the Platte River Valley documented feeding sites have been within approximately 4.8 km (3 miles) of the river.

9. Isolation from human developments such as roads, houses, and railroad tracks. Usually the roost is at least 0.4 km (0.25 mile) from such developments.

10. A certain type of sandbar in the immediate vicinity of the roost. All documented roosts had sandbars nearby although the number and size of the bars varied among sites. Sandbars usually had the following characteristics in the vicinity of the roost - gradual slope into the water (often less than 1-2° slope), little topographic relief (often less than 0.3 m [1 foot]), no banks over a few centimeters high, and little or no vegetation.

Roosting Behavior

Whooping cranes loaf on the above-mentioned sandbars and roost in the adjacent shallow, quiet water. These sandbars may be more secure from the approach of potential terrestrial and avian predators because the sandbars are away from the river's edge.

Disease Susceptibility

Although no whooping cranes are known to have died from avian cholera it can be speculated that they are susceptible to the disease because sandhill cranes have occasionally died from it. Additional studies need to be completed to accurately determine this susceptibility (R. Windingstad pers. comm.).

RECOMMENDATIONS FOR MANAGING THE PLATTE RIVER AND NEARBY AREAS FOR WHOOPING CRANES

As is true of other species such as the sandhill crane (Lewis et al. 1977), the key to managing whooping cranes in the Platte River Valley is habitat acquisition and maintenance. Evidence presented here and in other reports (USFWS 1981) underscores the need to prevent further deterioration and loss of habitat along the Platte River and in nearby areas.

The primary habitats that need to be acquired and managed for whooping cranes are river channel and native grassland to provide roosting and feeding sites. Priorities for acquisition should be established as follows. Top priority should be given to river channel habitat within the stretch from Lexington to Grand Island (R. Lock pers. comm.). Optimal sections of channel should be over 155 m (170 yards) wide, have many bare sandbars, be isolated from human developments, and be close to suitable feeding habitat. Second priority for acquisition should be "wet meadow" (see Frith 1974 for a definition) and native grassland habitat near the river. Ideally, long stretches of river channel in association with large tracts of adjacent "wet meadow" and native grassland habitat should be preserved at evenly spaced intervals throughout the Lexington to Grand Island region. In areas where the latter 2 habitats are not available, tame pasture or cultivated field habitat should be acquired.

Large wetlands in the Rainwater Basin area should be the next priority for acquisition. Further losses of wetland habitat in this area will result in greater crowding of waterfowl and crane populations and probably increase in outbreaks of avian cholera (USFWS 1981, Krapu and Pearson this proceedings); this could be disastrous to the whooping crane population. Wetland acquisition will allow management designed to minimize future outbreaks of cholera (R. Lock pers. comm.).

Fourth priority should be given to acquisition of optimal river channel habitat and native grasslands outside the Lexington to Grand Island zone but within the primary migration corridor. Final priority is given to acquisition of degraded river channel habitat within the critical habitat zone with the hope that it can be restored to better condition.

Habitat acquisition efforts should continue to be spearheaded by private conservation organizations such as the Platte River Whooping Crane Habitat Maintenance Trust, The Nature Conservancy, and National Audubon Society, all of which are currently active in the Platte River Valley (J. VanDerwalker and R. Wicht pers. comm.)

Management of river channel habitat involves maintenance of water levels and vegetative management. Water flow regimes must be maintained during spring (late March to early May) and fall (early October to mid-November) migration periods because whooping cranes need water for roosting (Johnson and Temple 1980). Water rights may have to be leased or purchased to insure adequate flows.

Vegetation management involves preventing the germination and establishment of seedlings on sandbars, and removing already established vegetation. Germination and establishment can be prevented primarily by maintaining water levels during summer (mid-May to August)(USFWS 1981). Vegetation removal can be accomplished by a variety of means including manual clearing, mechanical clearing, burning, island obliteration (clearing and leveling), herbicide spraying, and water flow maintenance (Aronson and Ellis 1979). Maintaining water flows in late winter would facilitate ice formation and subsequent flushing of ice during breakup; this would increase scouring and the concomitant removal of vegetation from sandbars (Ellis et al. 1981, R. Lock pers. comm.). The most promising manipulative techniques in terms of cost, efficiency, and effectiveness are probably burning and island obliteration (Aronson and Ellis 1979).

To be used by whooping cranes, "wet meadow" and native grassland habitat must be maintained in an open condition with short vegetation. This can be accomplished through implementation of a managed grazing system, periodic controlled burns, cutting, or a combination of these. Telephone lines, power lines, and fences should be removed or relocated from the vicinity of feeding areas and between roosting and feeding areas to minimize the potential for collisions.

River channel, "wet meadow," and native grassland habitat must be monitored periodically to insure that they are being maintained in optimal condition. A monitoring plan and schedule should be developed.

The Platte River Valley and Rainwater Basin area must be intensively monitored during both migration seasons (late March through early May and late September through mid-November) to detect use by whooping cranes at the earliest possible time. This is very important because cranes using cholera outbreak areas need to be detected quickly and "hazed" from the area to minimize exposure, and cranes using the river need to be protected from unnecessary human harassment. Early morning (before cranes leave their roost) fixed-wing aircraft flights during the migration seasons would be the most efficient means to detect use on the Platte River. In the Rainwater Basin area, early evening flights or both morning and evening flights would be desirable to minimize detection time. Ground monitoring by public agencies (e.g., Nebraska Game and Parks Commission and U.S. Fish and Wildlife Service) would minimize harassment.

To better manage whooping cranes in the Platte River Valley and nearby areas, additional data are needed on their behavior and ecology. Some data can be collected by monitoring personnel if they are properly trained. However, sufficient detailed data will only be obtained through radio-tracking studies; such studies were initiated in fall 1981 (R. Drewien pers. comm.). Comprehensive studies of the avian cholera problem in the Rainwater Basin area need to be completed so that this threat to whooping cranes and other water birds is minimized or eliminated. Such studies have been recently undertaken by the National Fish and Wildlife Health Laboratory (USFWS), Madison, Wisconsin (R. Windingstad pers. comm.). Management of wetlands in the Rainwater Basin is currently limited to water level maintenance and retrieval of dead birds (A. Trout pers. comm.). A more detailed plan should be developed to minimize the avian cholera problem. A contingency plan for "hazing" whooping cranes from outbreak areas has been implemented cooperatively by the Fish and Wildlife Service and Nebraska Game and Parks Commission (A. Trout pers. comm.).

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NESTING HABITAT OF SANDHILL CRANES IN CENTRAL ALBERTA

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Abstract: Six sandhill crane (*Grus canadensis*) nest sites were studied near Fawcett, Alberta, in June and July 1977. Mean water depth 1 m from nests was 16 cm (range 8-28 cm). Crane nests occurred a mean of 228 m (107-515 m) from open water and a mean of 50 m (30-79 m) from upland ridges. Cranes nested successfully 2.33 km from an area of regular human activity, though the mean was 4.92 km. The nesting area was a mosiac of 4 habitat types: upland ridge, muskeg, open sedge marsh, and open water. All crane nests were located in sedge marshes. Cover values were estimated for 110 plant species observed in 240 quadrat samples collected along transects at the 6 nests. Nest sites were compared using community coefficients calculated from relative cover values. Nests were an average of 57.1% similar. Qualitative comparisons were made between nesting patterns and habitat in central Alberta and those described by other authors in other regions.

Available data indicate that sandhill cranes exhibit diversity in nesting habitat. The majority of habitat studies to date have dealt with breeding populations in the United States. Due largely to the inaccessibility, few studies have been made of sandhill crane nesting grounds in central and northern Canada. Investigations are, therefore, at the descriptive stage. Quantitative studies are necessary before variability in crane nesting habitat can be evaluated between and within regions. The purpose of this paper is to provide a quantitative and qualitative description of the nesting habitat of sandhill cranes in 1 accessible region of central Alberta.

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STUDY AREA

The study area consisted of approximately 150 km^2 between the Athabasca and Pembina Rivers, west of Fawcett and Flatbush, Alberta, Canada. This area is locally known as Athabina and is located in central Alberta, 220 km northwest of Edmonton (Fig. 1).

The study area lies within the boreal forest phytogeographic region as described by Moss (1955). Athabina is characterized by an undulating topography dissected into well-drained forested uplands and poorly drained lowlands covered with muskeg, marsh, or open water. The soils on the uplands are characterized by a thin surface horizon of semidecomposed leaf material which covers a narrow, leached, sandy A horizon over a base of Aeolian sand. The soils in the muskegs and marshes are organic.

METHODS

Nesting Patterns

Helicopter, fixed-wing aircraft, and ground searches were used to locate sandhill crane nests during May 1977. Nests found during aerial and ground searches were visited to gather data on water depths and nesting patterns. Four water depth measurements were taken at each nest, 1 m from the nest edge, to allow for any submerged portion of the nest mound. Distances from nests to nearest open water, upland ridge, and area of regular human activity were measured on the ground or from aerial photographs.

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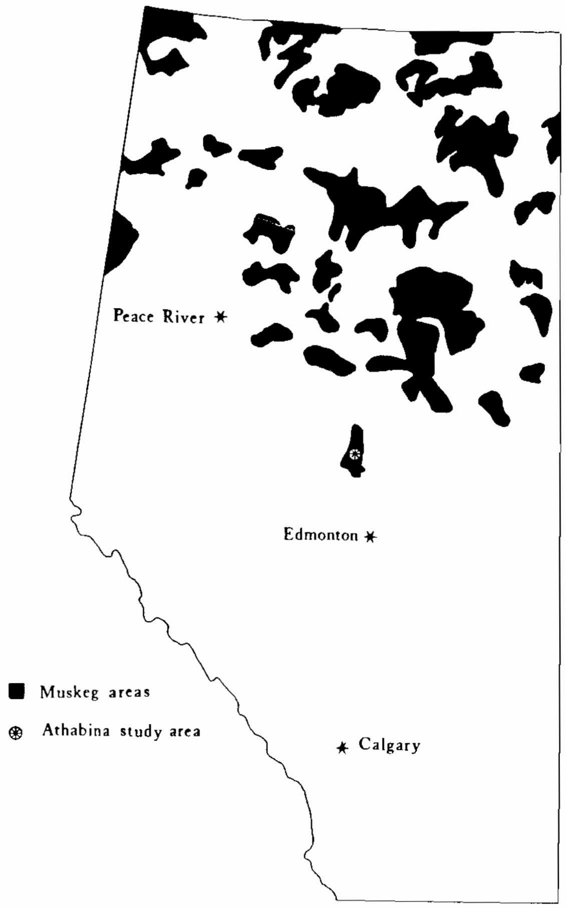

Fig. 1. Location of Athabina study area and other muskeg areas in Alberta.

Table 1. Distance from sandhill crane nests in Alberta to nearest human activity, ridge, and open water.

Site	Distance from nest to: Human activity (km)	Ridge (m)	Open water (m)
1	2.3	45	107
2	8.5	79	129
3	3.9	45	120
4	5.4	51	515
5	6.7	30	386
6	2.8	47	112
Mean	4.9	50	228
Range	2.3-8.5	30-79	107-515

Sampling of Vegetation

During June 1977, plants from the Athabina area were collected, identified, pressed, and filed for future reference. Authorities used in these and all subsequent identifications were Moss (1959) and Cormack (1967).

Between 6 July and 22 July 1977 the nests on the Athabina area were revisited to gather information on vegetation. From each nest, 100-m transects were extended in the 4 cardinal directions. Vegetation was sampled using a total of 40 quadrats placed at 10-m intervals along and perpendicular to these transects. Distance and direction of each quadrat from the transects was randomized using a 2-decimal random numbers table. Quadrat size was 0.25 m^2 in the marsh and 100 m^2 on the uplands. The percent of ground covered by the shadows of each species (assuming the sun at zenith) was estimated within each quadrat and a cover code (described by Daubenmire 1968:42-44) recorded according to ranges of cover. The midpoints of these ranges (0-5%, 5-25%, 25-50%, 50-75%, 75-95%, 95-100%) were used in the subsequent calculations.

Analysis of Vegetation

Each nest site was considered as a unit. Relative cover values (percent of total cover) were computed by site for each plant species found at that site. These relative cover values were used as the basis for intersite comparisons using community coefficients (Oosting 1956:77). Relative cover estimates of individual species were also summed by site according to growth form.

Plant species information was also pooled across nest sites. Plant species were ranked according to total average cover values calculated on the basis of the total number of samples examined in the study (240). The number of sites in which each species was found (presence) was also determined.

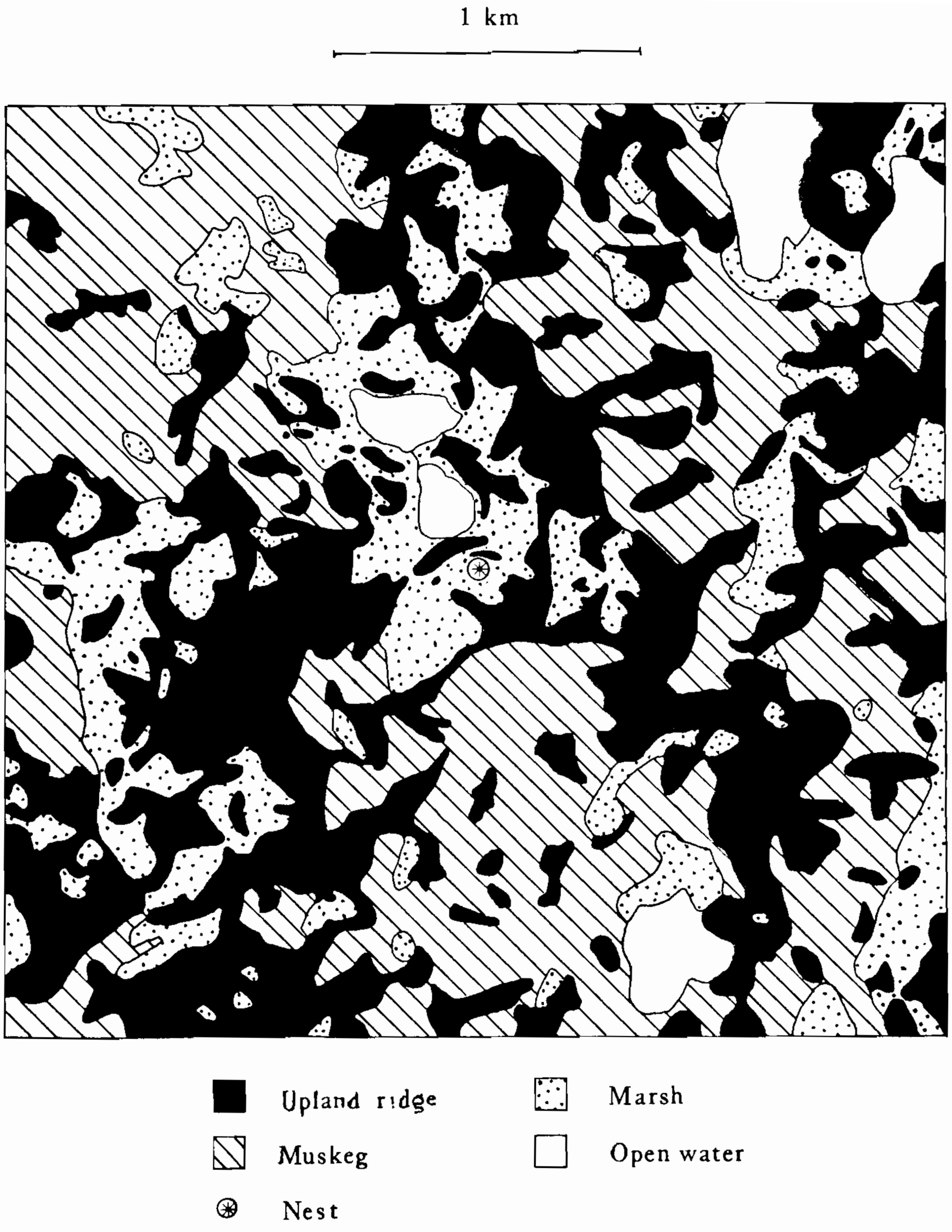

Fig. 2. Distribution of habitat types within a 10.4 km^2 area around sandhill crane nest #2 in Athabina, Alberta.

RESULTS

Nesting Patterns

All crane nests were located in open, wet, sedge marshes and in most circumstances were adjacent to a small patch of low, shrubby cover of either bog birch (*Betula pumila*), or glaucous bog willow (*Salix pedicellaris* var. *hypoglauca*). Distances from the nests to the nearest ridge varied from 30 to 79 m (Table 1). Distance to open water (lake or stream) varied from 107 to 515 m, and distance to an area of regular human activity varied from 2.3 to 8.5 km.

Water depths 1 m from nest mounds averaged 16 cm, and ranged from 8 to 28 cm. In 4 of the 6 marshes studied, the water depths in other portions of the marsh varied little from the water depths measured at the nests themselves. At Site 5, however, the water in the majority of the marsh was about 35 to 45 cm deep, although 4 measurements taken 1 m from the nest averaged only 17 cm. Similarly, at Site 6 the water in most of the marsh and up to within 8 to 10 m of the nest was approximately 1 to 1.5 m deep, though the depth at the nest averaged only 22 cm.

Vegetation

The Athabina area was a complex mosaic of habitat types: forested upland ridges, spruce and tamarack muskegs, open sedge marshes, and open water (Fig. 2). The 50 various-sized lakes (and also the majority of the crane nests), were concentrated in the eastern half of the area.

The dominant vegetation of the upland ridges varied from moderate to dense mixed stands of white spruce (*Picea glauca*), trembling aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*), to monotypic, nearly park-like stands of jack pine (*Pinus banksiana*). Shrub growth was most dense under a moderate canopy, and practically absent under dense stands of jack pine or in xeric, grassy openings which commonly occurred at the ridge crests. Low, wet ridge margins were dominated by black spruce (*Picea mariana*) and various willows (*Salix* spp.).

Muskegs in the area were of 2 types: spruce muskegs, characterized by dense stands of black spruce; and more mesic, open tamarack (*Larex laricina*) muskegs. Shrub cover of Labrador tea (*Ledum groenlandicum*) in the spruce areas gradually gave way to swamp birch in the wetter areas. The floor of both muskegs was comprised of uneven hummocks of graminoids, deadfall, small water-filled openings, and a thick covering of various bryoids dominated by sphagnum mosses (*Sphagnum* spp.). Under more hydric conditions, the open tamaracks gave way to low, sparse shrub cover of swamp birch, hoary willow (*Salix candida*), and glaucous bog willow in an otherwise open marsh.

Open marshes were quite similar, dominated by 4 species of sedge (*Carex gynocrates, C. lasiocarpa*, *C. limosa*, and *C. praegracilis*), various forbs, and the sparce, low shrubs mentioned above. Many of the marshes were merely thin, floating mats of dead vegetation.

A total of 240 samples of vegetation was made at the 6 nest sites. No samples fell within spruce or tamarack muskeg, though an occasional tamarack was found in drier marsh areas. One sample occurred on open water. The majority of samples occurred in marsh habitat (186 or 77.5%); 33 (13.8%) were located on upland ridges and 20 (8.3%) occurred in border areas (those samples containing both marsh and ridge habitat).

Estimates of relative cover of 110 plant species and other physiographic variables (e.g., open water, deadfall, and others) were used to describe and compare nest sites. When nest site information was pooled to determine relative average cover values, dominant cover types at nest sites were open water (44.13% AC), dead graminoids (13.45% AC), *Sphagnum* spp. (10.96% AC), and vegetative graminoids (10.17% AC)(Table 2). Forbs, graminoids, shrubs, and open water were dominant cover types at all nest sites (Table 3). Species-specific estimates of relative cover (Carlisle 1979) were used to calculate community coefficients for nest sites. Nest sites were an average of 57.1% similar, with a range of 40.4% to 70.5% (Table 4).

DISCUSSION

Nesting Patterns and Breeding Habitat

Descriptions of crane nesting habitat should include not only a general description of the area, but should emphasize those characters that may be important to nesting cranes. Open water, upland feeding areas (in acid regions), and a lack of human disturbance are common denominators in the qualitative studies conducted thus far on sandhill crane nesting habitat in various portions of the birds' range (Table 5).

Howard (1977:15) states that "the presence of water is the most important single item in crane nesting habitat." Open shallow water provides important roosting sites for nonincubating and prebreeding cranes during the spring and summer in Michigan (Warback 1976). Taylor (1976) reported that all crane nests in the Upper Peninsula of Michigan were closely associated with water or were located on unstable bog mats.

Results of this study were comparable with others and indicate that water was important to nesting cranes. Although cranes were not observed roosting in any of the lakes in Athabina, crane nests were located an average of 228 m (107-515 m) from open water. None of the nests were located more than 1 km from open water, and nests were not found on the large marshes northwest of Athabina which lacked open water.

Table 2. Plant species and physiographic variables ranked in descending order of percent average cover, calculated on the basis of all 240 samples, and number of sandhill crane nest sites at which these plants or characteristics were found.

Rank	Species	% average cover	No. nest sites	Rank	Species	% average cover	No. nest sites
1	Open water	44.1	6	27	*Carex praegracilis*	2.5	6
2	Dead graminoids	13.5	6	28	*Picea glauca* (adult)	2.4	6
3	*Sphagnum* spp.	11.0	6	29	*Lonicera involucrata*	2.3	6
4	Vegetative graminoids	10.2	6	30	*Populus tremuloides* (adult)	2.2	4
5	*Salix pedicellaris* var. *hypoglauca*	6.5	6	31	*Triglochin maritima*	2.2	5
6	*Betula papyrifera*	6.3	6	32	Unknown graminoids (hills)	2.2	6
7	*Carex lasiocarpa*	5.7	6	33	*Alnus crispa*	2.1	4
8	*Carex limosa*	5.6	5	34	*Elymus innovatus*	2.1	5
9	*Vaccinium vitis-idaea*	5.5	6	35	*Populus tremuloides* (sapling)	2.1	5
10	*Menyanthes trifoliata*	5.3	6	36	*Cornus canadensis*	2.0	6
11	*Carex gynocrates*	4.8	6	37	*Ledum groenlandicum*	1.9	5
12	*Rosa* sp.	4.1	6	38	*Salix bebbiana*	1.8	6
13	*Aralia nudicaulis*	3.9	5	39	*Equisetum palustre*	1.7	6
14	*Vaccinium myrtilloides*	3.8	5	40	*Amelanchier alnifolia*	1.7	6
15	*Linnaea borealis*	3.8	6	41	*Rubus strigosus*	1.4	6
16	*Potentilla palustris*	3.7	6	42	*Prunus pensylvanica*	1.4	5
17	*Arctostaphylos uva-ursi*	3.3	6	43	*Galium boreale*	1.3	5
18	*Epilobium angustifolium*	3.2	6	44	*Sheperdia canadensis*	1.2	5
19	*Betula pumila*	3.2	6	45	*Salix pseudomonticola*	1.2	6
20	Deadfall	3.1	6	46	*Aster laevis*	1.1	6
21	*Picea mariana* (adult)	3.1	5	47	*Equisetum scirpoides*	1.1	4
22	*Andromeda polifolia*	3.0	4	48	*Picea mariana* (sapling)	1.0	5
23	*Equisetum arvense*	2.9	5				
24	*Equisetum fluviatile*	2.8	5				
25	*Cladina* sp.	2.6	5				
26	*Maianthemum canadense*	2.6	4				

[a] See Carlisle (1979) for list of plant species with <1% average cover.

In northern Michigan and central Alberta, where marsh water was slightly acid, cranes left the nest marshes to feed primarily in clearings in the surrounding forest highlands (Walkinshaw 1949:44). Cranes were flushed from ridge clearings in Athabina on only 4 occasions during 1976-77, despite a mean distance of crane nests to the nearest dry ridge of only 50 m.

Taylor (1976:46) reported that no cranes found in the Upper Peninsula of Michigan nested near human activity and that "the size of the nesting bog is less important than isolation from human disturbance." In Athabina, cranes nested no closer than 2.3 km to human activity. However, in Wisconsin, Howard (1977) found cranes nesting successfully only 0.49 km from human activity. This

Table 3. Relative cover estimates (% total cover) by growth form, number of species, and sample size by habitat types, of vegetation samples near 6 sandhill crane nests in Alberta.

	% total cover at nest site					
Category	1	2	3	4	5	6
Trees						
Conifers	5.3	3.6	2.7	5.0	4.8	1.8
Broadleaves	7.9	0.6	1.6	8.8	8.1	3.7
Shrubs	17.3	14.5	14.1	12.7	20.1	8.5
Forbs	32.5	10.2	25.9	25.2	33.4	20.3
Graminoids	18.6	36.1	28.2	18.6	11.5	23.6
Bryoids	5.2	5.7	7.6	7.2	7.6	3.3
General						
Open water	11.3	28.8	18.7	19.9	11.5	35.7
Deadfall	1.0	0.6	0.7	1.2	2.0	2.5
Miscellaneous	0.9	--	0.6	1.4	1.0	0.5
TOTAL	100.0	100.1	100.1	100.0	100.0	99.9
NUMBER OF SPECIES	80	52	66	72	83	57
NUMBER OF SAMPLES						
Marsh	29	36	36	29	20	36
Ridge	5	4	1	7	14	2
Border	6	0	3	4	6	1

apparent tolerance of human disturbance may be due to the loss of preferred nesting areas through drainage of wetlands for agriculture.

Nesting habitat of sandhill cranes in other parts of their range has been described by several authors (Table 6). The majority of these descriptions are qualitative and can be compared with this study on that basis. The nest sites described in this study appear most similar to those described in central Wisconsin (Howard 1977), the Upper Peninsula of Michigan (Taylor 1976), and the Yukon-Kuskokwim Delta, Alaska (Boise 1977). Sphagnum mosses and various species of sedges or grasses are common to all those areas. The least similar nesting area occurred on dry sand dunes on Banks Island, Northwest Territories (Walkinshaw 1965a).

Table 4. Percent similarity of 6 sandhill crane nest sites in Alberta (expressed by community coefficients).

Nest site	% similarity among nest sites				
	1	2	3	4	5
1					
2	53.2				
3	63.8	67.4			
4	61.9	58.7	67.9		
5	58.6	42.8	70.5	63.2	
6	47.2	60.7	51.8	48.6	40.4
Mean	57.1				
Range	40.4-70.5				

Comparison of Nest Sites in Athabina

Coefficients of community, calculated from relative cover values, were used in this study to compare nesting sites within the study area. This coefficient is 1 of many similarity indices currently used by botanists. Mueller-Dombois and Ellenburg (1974:278) write:

"Theoretically, the similarity indices could vary from zero to 100 percent, i.e., from complete dissimilarity to perfect similarity.

Table 5. Distances from sandhill crane nests to important habitat characteristics in various regions.

Location	Authority	Mean water depth at nest (cm)	Ridge or dry land (m)	Mean distance from nest to Open water (m)	 Human activity (km)
Central Alberta	This study	16 (8-28) n = 10	50 (30-79) n = 6	228 (107-515) n = 6	4.9 (2.3 minimum) n = 6
Michigan	Walkinshaw (1949)	17.52 n = 37	185 (15-670) n = 39		
Central Wisconsin	Howard (1977)	12.6 (0.1-35.7) n = 50		280 (11-1,280) n = 50	2.7 (0.5-9.0) n = 50
Oregon	Walkinshaw (1949)	38.3 (30-52) n = 3			
Idaho	Walkinshaw (1949)		each <50 n = 3		
Florida	Thompson (1970)	25.0 (2.5-99.1) n = 44			
Yukon-Kuskokwim Delta, Alaska	Boise (1977)			<50	

. . . The similarity of two replicate stands may be nearer to 75 percent than to 100 percent." Because of inaccuracies inherent in sampling procedures, a community coefficient of about 75% would not be uncommon in comparisons of replicate samples of the same area.

The community coefficients calculated for the Athabina area indicate that the cranes' nesting sites are quite similar. The mean for the 15 site comparisons was 57.1%, with a range of only 40.4% to 70.5%. These comparisons of the sites as entire units were useful as indicators of similarity in the area. Carlisle (1979) further analysed variability between sites by grouping samples within sites according to habitat type and then calculating intersite community coefficients for the marsh, ridge, and border components of the sites.

Comparisons of community coefficients are needed in the same area with values calculated from randomly selected marshes where cranes do not nest. Such comparisons would determine if cranes are actively selecting nest sites based on specific required characters, or if the similarity exhibited between the nest sites is a reflection of the homogeneity of the region.

Applications to Crane Management

The relative cover values presented in Table 3 can be used in the future as a basis for direct comparison of nest sites in Athabina with those similarly studied in other portions of the boreal forest. These comparisons would determine the degree of variability present in nesting habitat of sandhill cranes in this region and thereby increase our understanding of the cranes' habitat tolerances and requirements. Knowledge of these habitat variables is necessary before the ecologist can evaluate possible future impacts to sandhill crane nesting areas caused by activities such as oil development, lumbering, peat mining, and draining of wetlands for agricultural purposes.

There are many questions still be be answered regarding the population size, breeding habitat, and distribution of sandhill cranes within the Canadian boreal forest regions. Few studies have been made of these areas largely due to the expense involved in large-scale surveys. Habitat information from this and similar studies could be used to develop a model of nesting habitat parameters for sandhill cranes in the boreal forest. This model, combined with advances in remote sensing technology (e.g., the LANDSAT system), could reduce logistics problems by more easily identifying potential breeding areas within the Canadian boreal forests.

Table 6. Comparison of sandhill crane nest habitats in various regions.

Location	Authority	General description	Plants adjacent to nest
Central Alberta	This study	Open sedge marsh	*Salix pedicellaris* or *Betula pumila*, *Sphagnum* spp., sedges, and forbs
Lower Peninsla Michigan	Walkinshaw (1965b)	Marsh	Cattails (*Typha* spp.) and sedges
Upper Peninsula, Michigan	Taylor (1976)	Sphagnum bog	*Sphagnum* spp., leather-leaf (*Chamaedaphne calyculata*), cotton grass (*Eriophorum* spp.), black spruce, jack pine
Malheur NWR, Oregon	Littlefield and Ryder (1968)	Open meadows or marshes	Broad-fruited burreed (*Sparganium eurycarpum*), hardstem bulrush (*Scirpus acuta*), broad-leaved cattail (*Typha latifolia*), grasses or forbs
Yukon-Kuskokwim Delta, Alaska	Boise (1977)	Heath-marsh mosaic, sedge grass meadow	*Sphagnum* spp., *Carex lyngbyaei*, *Carex rariflora*, *Elymus arenarius*, *Festuca rubra*, *Arctagrostis latifolia*
Central Wisconsin	Howard (1977)	Various wetlands types	*Carex rostrata*, *Sphagnum* spp., *Scirpus cyperinus*, *Carex lasiocarpa*, *Salix* spp., *Typha latifolia*, *Spirea tomentosa*, *Carex oligosperma*, *Calamagrostis canadense*
Banks Island, NWT	Walkinshaw (1965a)	Dry sand dunes	Sparse grasses and sedges

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NESTING OF THE FLORIDA SANDHILL CRANE IN CENTRAL FLORIDA

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Abstract: One hundred and thirty-seven Florida sandhill crane (*Grus canadensis pratensis*) nests were observed between 1938 and 1981; 81 were located in ponds less than 4.1 ha and 56 were in larger wetlands. Sixty nests were in ponds where the great portion of surrounding habitat was pasture; 30 where it was saw palmetto; 6 where it was pine forest; the remainder where the habitat was a combination of pasture, saw palmetto, pine forest, cypress, bayheads, shrubs, oak hammocks or cabbage palm hammocks. One hundred twenty-four of 137 nests were built where pickerelweed and maiden cane grass were the dominant emergent pond vegetation. All except 1 of the nests were in shallow water.

Egg-laying was known or estimated (from the hatching date allowing 30 days for incubation) for 9 to 14 nests annually: 3-5 March 1970, 11-12 March 1971, 22-23 February 1972, 15-16 February 1973, 28 February-1 March 1974, 1-3 March 1975, 1-3 March 1976, 30 January-1 February 1977, 3-5 February 1979, 3-5 March 1980, and 1-3 March 1981. During 1977, laying came immediately following the coldest period of winter; pond vegetation had been frozen badly and temperatures were still cool. However, nesting began 1 month earlier than normal. During 1973, 1977, and 1979 excellent precipitation came in the winter months so the ponds were full of water by January. Winter rains apparently were the factor stimulating nesting. Annual rainfall did not seem as important as the amount of rainfall from October until January.

Where the outcome was known, 92 of 119 nests were successful (77.3%). Among 224 eggs, 176 hatched and 174 chicks left nests (77.7%). Feral hogs and raccoons were the chief predators. There were 7 clutches of 1 egg and 114 of 2 eggs (mean 1.94). In 82 nests 2 chicks left the nest and in 10 only 1 chick left.

Some ranches remain intact, but several have been split in ownership. Four ranches recently owned by cattlemen are now owned by developers and on 1 ranch 0.1-ha lots have been sold. Ditches are still dug periodically and many ponds have been drained. On some ranches partial land use has changed from cattle grazing to sod farming, citrus, and tomato growing. On nearly every ranch the cranes have lost habitat. Conditions become so severe during drought years that only about 50% of the paired cranes nest.

Continued studies of the nesting and populations of the Florida sandhill crane have brought forth much additional information on this subspecies since my earlier report (Walkinshaw 1976). Most of the field work was carried on the Kissimmee Prairie by motor vehicle or on foot but a helicopter was used in March 1976 for 3 hours and in 1981 for 4 hours.

WETLANDS

Central Florida wetlands do not fit exactly into standard wetland classifications; consequently, the following classification was used:

Type 1, Periodic Flooded Plain or Flat.--Soil covered with water or waterlogged during periodic rainy periods, well drained most of year.

Type 2, Grass and Sedge Meadow.--Chiefly maiden cane grass (*Panicum hemitomum*) with little shallow water.

Type 3, Shallow Marsh.--Soil normally waterlogged during spring and summer, covered nearly all the time by as much as 25 cm of standing water with emergent vegetation all over or in patches.

Type 4, Deep Marsh.--Similar to Type 3 but with more than 25 cm of standing water during most of year. Emergent vegetation most often in clumps or patches; pickerelweed (*Pontedaria lanceolata*) and maiden cane the most common plants. Open water areas often grown to submerged vegetation such as water hyssop (*Bacopa monnieri*) and bladderwort (*Utricularia* - several species).

Type 5, Open water.--Sometimes grown to spatterdock (*Nuphar macrophyllum*) or waterlily (*Nymphaea odorata*), especially along water's edge.

Type 6, Shrub Swamp.--Bayheads, grown to trees (*Magnolia grandiflora*, *M. virginiana*, *Persea borbonia*, *Pinus palustris*, *Acer rubrum*), but mostly shrubs such as buttonbush (*Cephalanthus occidentalis*), edlerberry (*Sambucus simpsonii*), willow (*Salix* sp.), waxberry (*Myrica cerifera*), fetterbush (*Lyonia lucida*), and others, with the entire region covered periodically by standing water.

Type 7, Wooded Swamp.--Covered with the above trees and grown to tangles of grapevine (*Vitis* sp.), poison ivy (*Rhus radicans*, *R. vernix*), and a variety of greenbriar (*Smilax* sp.) with standing water in places.

For additional subclassifications: (A) - size of wetland less than 4.1 ha and (B) size more than 4.1 ha. Alphabetical lower case letters are used as follows if 50% or more of the wetland is bordered by the following: (a) Pastured fields; (b) saw palmetto (*Serenoa repens*); (c) bayheads; (d) shrubs; (e) pine forest (*Pinus elliottii*, *P. palustris*); (f) oak hammocks, live oak (*Quercus virginiana*), water oak (*Q. nigra*), and other oaks; (g) cabbage palm hammocks (*Sabal palmetto*); (h) cypress (*Taxodium distichum*, *T. ascendens*); and (i) other vegetation.

Following the above classification, 137 nests have been found as follows: 3Aa (10 nests), 3Ab (2), 3Ba (1), 3Bb (2), 4Aa (50), 4Ab (11), 4Ae (2), 4Ah (1), 4Abe (5), 4Ba (31), 4Bb (15), 4Bab (2), 4Bc (2), 4Bcd (1), 4Beb (1), and 4Bae (1). Thus 36.5% of nests were found in Type Aa and 77.4% in the wetland types 3Aa, 4Aa, 4Ba, and 4Bb.

Nests were found in wetlands where the chief plants in the vicinity were pickerelweed and maiden cane grass. One hundred twenty-four of the 137 nests were built where these 2 plants dominated the emergent vegetation. In all 124 nests these 2 plants were used to construct nests. However, it was evident the cranes preferred to pull off stalks of maiden cane, if it was nearby, even though they preferred to build their nests in patches of pickerelweed (Table 1).

Table 1. Predominant vegetation adjacent to Florida sandhill crane nests and materials used in nest construction.

Predominant vegetation near nest	Times found[a]	Species used predominantly in nest construction
St. John's wort (*Hypericum fasciculatum*)	2	2
Arrowleaf (*Sagittaria lancifolia*)	2	2
Maiden cane (*Panicum hemitomum*)	21	26
(*Panicum woodwardii*)[b]	1	1
Bluestem (*Andropogon floridanus*)	2	2
Bulrush (*Scirpus* sp.)	1	1
Spike rush (*Eleocharis equisetoides*)	2	2
Water hyacinth (*Eichhornia crassipes*)[c]	1	1
Pickerelweed (*Pontedaria lanceolata*)	89	84
(*Juncus effusus*)	2	2
(*Pontedaria lanceolata* and *Panicum hemitomum*)	14	14
Total	137	137

[a] In 1 instance an unidentified grass was used, in another nest a mass of flotsam was used, including water hyssop (*Bacopa monnieri*). Maiden cane and/or pickerelweed were used in 90.5% of all nests.

[b] This nest was found in a dry habitat at Archbold Biological Station, Highlands County by their personnel.

[c] This nest was found by Stephen Nesbitt at Payne's Prairie, Alachua County.

Table 2. Pond size and water depth where Florida sandhill cranes nested, and distance from nest to shore.

Year	Wetland status	Nests	Mean pond size (ha)[a]	Range in pond size (ha)	Mean distance to shore (m)	Range in distance to shore (m)	Mean water depth (cm)	Range in water depth (cm)
1938	Wet	3	17.2	0.8-48.6	46.8	37-58	25.0	20-30
1945	Dry	6	(in Okefenokee Swamp, Ga.)				28.7	0-46
1960	Wet	2	(in Okefenokee Swamp, Ga.)				30.5	0-61
1966-68	Wet	7	4.2	0.6-8.1	62.2	46-85	25.5	10-46
1970	Wet	9	3.2	0.6-10.1	68.4	22-153	44.7	26-63
1971	Dry	9	4.5	0.4-10.1	53.3	35-91	19.5	0-41
1972	Wet	9	3.5	0.2-10.1	54.9	18-122	30.1	0-61
1973	Wet	13	2.4	0.2-8.1	64.0	15-183	32.7	15-45
1974	Dry	16	5.2	0.2-18.2	58.5	11-122	30.4	12-74
1975	Dry	10	3.7	0.4-10.1	44.5	12-107	26.6	0-95
1976	Dry	12	4.4	1.6-8.9	43.2	8-91	17.0	0-41
1977	Slightly wet	8	4.7	0.8-10.1	61.0	46-69	26.6	4-45
1978	Very wet	0						
1979	Wet	10	2.0	0.4-6.5	54.5	18-123	35.7	25-49
1980	Wet	10	2.5	0.2-6.5	54.7	9-179	42.8	20-74
1981	Dry	11	5.1	1.0-14.6	62.1	20-65	22.4	15-32
Mean		135[b]	3.8	0.2-48.6	56.3	8-183	29.6	0-95

[a] Sizes of ponds estimated from topographic maps and aerial photographs. During dry years they were often smaller. During wet years cranes appeared to use smaller ponds, even in 1938 when ponds had not yet been drained.

[b] Mean pond size and distance to shore is based on 131 nests; mean water depth is based on 130 nests.

All but 1 of 139 central Florida nests have been built in small ponds and surrounded entirely or with patches of shallow water and emergent vegetation. Table 2 summarizes water depths when nesting began, and the size of nesting ponds. The amount of precipitation is also listed for the Lake Wales area (Table 3).

Precipitation is definitely the most important factor determining whether cranes nest and when they nest in central Florida. Temperature apparently has little effect. Increased daylight length apparently has some effect because cranes normally begin nesting during the first 2 months of the year. But the amount of water in the nesting pond or ponds in the territory of a pair of cranes definitely affects their nesting.

A great majority of ponds were dry in 1981 when I found 11 nests (4 by helicopter), all in ponds with some water. Eleven pairs were found that showed no signs of nesting; all the ponds on their territories were dry. I checked the latter ponds in Osceola and Polk Counties from the ground and also flew over these territories in a helicopter. There was more water in Okeechobee County wetlands. In some ponds, even with good water, nests were built but eggs were not laid, indicating that availability of food might influence laying.

Table 3. Precipitation (cm) recorded at Warner Turnquist weather station, Lake Wales, Florida.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1970	5.4	7.3	18.5							5.4	1.7	4.9	112.4
1971	0.4	13.8	2.7	0.9	8.0	21.8	12.9	15.7	7.9	19.1	4.0	3.1	110.6
1972	3.3	13.6	2.6	6.8	7.0	19.6	15.2	14.4	2.6	6.0	6.7	6.5	104.4
1973	16.6	9.1	14.4	15.2	10.1	6.1	22.9	23.3	14.3	1.6	3.9	2.8	140.3
1974	1.2	2.8	1.7	3.1	13.0	36.0	24.9	21.7	13.0	0.6	0.6	4.6	123.3
1975	1.7	6.6	4.3	0.7	18.1	12.5	18.0	24.9	22.5	12.2	4.9	1.8	128.3
1976	2.1	0.8	3.5	5.8	33.0	21.4	17.9	21.9	23.5	7.7	18.5	5.5	161.8
1977	5.6	4.1	4.5	2.8	5.3	4.0	28.8	27.4	17.2	8.6	4.8	4.6	117.8
1978	6.1	9.4	6.5	2.4	23.6	24.3	31.3	10.4	10.5	3.3	2.0	9.1	138.9
1979	17.1	3.0	7.2	4.1	23.7	11.7	13.4	16.1	36.5	0.5	7.1	4.0	144.5
1980	1.0	9.7	4.0	3.9	15.5	10.1	15.8	6.3	3.6	3.4	11.0	2.2	87.1
1981	1.1	9.0	3.0										

EGG-LAYING

Egg-laying dates during different years were known or were estimated by backdating from the hatching dates. Mean laying dates were as follows: 3-5 March 1970, 11-12 March 1971, 22-23 February 1972; 15-16 February 1973, 28 February-1 March 1974, 1-3 March 1975, 1-3 March 1976 (10 nests), 30 January-1 February 1977 (9 nests), 3-5 February 1979 (14 nests), 3-5 March 1980 (9 nests), and 1-3 March 1981 (8 nests)(Table 4). Egg-laying was earliest during 1977 when 8 of 9 pairs laid their eggs by 1 February, most of them between 22 and 28 January. The coldest days of winter 1976-77 came on 19 and 20 January when the temperature was 26° F (-3.3° C). During 1979 the laying period covered a much wider range, 7 January-28 February (14 records), with the mean being 3-5 February. The coldest day, 29° F (-1.7° C) was 3 January.

During November 1976, 18.5 cm of rain was recorded at Lake Wales, quite comparable to the amount of rainfall in the entire region. The ponds were full when the birds began to nest in mid-January 1977. During December 1978 and January 1979, 26.2 cm of precipitation were recorded and the ponds were full at the beginning of January 1979. Actual mean egg-laying was only 4 days later than during 1977, yet the 1980 and 1981 egg-laying was 1 month later, 3-5 March and 1-3 March, respectively. The rains as recorded in the Lake Wales News for the 1979 nesting season were 7 December 1978 (6.3 cm), and in January 1979, 3 cm on the 12th, 3 cm on the 13th, 7.1 cm on the 14th, 1.5 cm on the 23rd, and 6.6 cm on the 27th. During the same period of 1979-1980 and 1980-1981 there was practically no rainfall; 1981 (Table 5) was the driest year since 1966 and nearly all the ponds were dry.

EGGS, INCUBATION PERIOD, CLUTCH SIZE, AND HATCHING SUCCESS

Eggs of the Florida sandhill crane are much lighter colored and appear to have fewer spots than those laid by greater, Canadian, and lesser sandhill cranes (*G. canadensis tabida*, *G. c. rowani*, and *G. c. canadensis*, respectively). Field measurements of 168 Florida sandhill eggs were 93.5 (80.9-107.6) x 59.8 (53.7-67.0) mm with the standard deviation each year varying between 2.5 to 6.1 mm in length and 1.3 to 3.0 mm in width. The mean weight of 55 eggs was 168.7 g (138.7-233.6).

The position of eggs in nests was recorded many times, or photographs were taken so that the position and the distance apart could be recorded. In 66 two-egg clutches the eggs averaged 17.1 mm (0-101) apart. In 27 clutches, the eggs faced the same direction; in 22 clutches they faced opposite directions and in 5 clutches they were at right angles with the small ends together. In 7 clutches they were at right angles with the large end of 1 egg adjacent to the small end of the other. Within 3 clutches the eggs were almost aligned. Clutch size averaged 1.94 eggs (7 of 1;

Table 4. A summary of the nesting season of Florida sandhill crane, 1976-77, 1979-81.[a]

Year	No. nests	Successful nests	Eggs laid	Eggs hatched	Chicks fledged	Extreme dates			Mean dates eggs were	
						Nests found	Eggs laid	Eggs hatched	Laid	Hatched
1976	10 (3)	7	19 (5)	13	13	20 Feb-29 Mar	7 Feb-23 Mar	8 Mar-20 Apr	1-3 Mar	27-28 Mar
1977	9	9	17	17	17	11 Feb-17 Mar	22 Jan-28 Feb	22 Feb-29 Mar	30 Jan-1 Feb	1-2 Mar
1979	14	13	27	25	25	12 Feb-17 Mar	7 Jan- 2 Mar	8 Feb-31 Mar	3-5 Feb	6-7 Mar
1980	9	8	16	15	15	1-28 Mar	18 Feb-13 Mar	19 Mar-11 Apr	3-5 Mar	1-2 Apr
1981	8 (3)	5	15 (5)	11	10	18 Feb-30 Mar	12 Feb-18 Mar	15 Mar- 2 Apr	1-3 Mar	28-29 Mar
Total 1976-1981										
	50 (6)	42	94 (10)	81	80	11 Feb-30 Mar	7 Jan-23 Mar	8 Feb-20 Apr	19-21 Feb	17-18 Mar
Total 1938-1981										
	119 (13)	92	224 (22)	176	174	2 Feb-12 Apr	7 Jan- 3 Apr	8 Feb-21 Apr	22-24 Feb	23-24 Mar

[a] Hatching dates were known for nearly all nests; laying dates for several. Estimated laying dates were determined by knowing hatching dates and allowing 30 days incubation. In some years there were not always 30 days between the mean laying period and the mean hatching period because some nests were destroyed by predators. Numbers in parentheses are the number of nests and eggs where the outcome was not known. For example during 1976 and 1981, 3 nests and 5 eggs were observed for which I was unable to learn their final outcome. The known nest success was 77.3% and the known egg success, 77.7%.

Table 5. Air temperature (°C) and rainfall at Lake Wales, Polk County, Florida, and egg-laying dates for Florida sandhill cranes, nesting seasons 1976-77, 1979-81.

Month	Mean high	Mean low	Mean	High	Low	Date when High	Date when Low	Rainfall (cm)	First[a] laying date	Mean[a] laying date
1976										
Jan	20.7	8.8	14.7	26.1	0.0	7 Jan	9 Jan	2.1	7 Feb	1-3 Mar (13)
Feb	24.1	11.6	17.8	29.4	2.8	18 Feb	3 Feb	0.8		
First ½ Mar	29.4	16.7	23.1	31.1	11.1	9 Mar	11 Mar	3.5		
Mean 75 days	24.0	11.7	17.9	31.1	0.0	9 Mar	9 Jan	6.4		
1976-1977										
Nov	23.2	13.2	18.2	28.3	3.9	28 Nov	23 Nov	18.5	22 Jan (2)	30 Jan - 1 Feb (9)
Dec	20.4	10.8	15.6	27.8	1.7	12 Dec	23 Dec	5.5		
Jan	15.9	6.0	11.2	25.5	-3.3	28 Jan	19,20 Jan	5.6		
Feb	21.8	8.7	15.3	30.0	1.1	27 Feb	17,18 Feb	4.1		
Mean 120 days	20.3	9.7	15.0	30.0	-3.3	27 Feb	19,20 Jan	33.4		
1978-1979										
Nov	27.5	16.9	22.2	30.0	15.0	29 Nov	13 Nov	2.0	7 Jan	3-5 Feb (14)
Dec	24.5	14.8	19.6	31.7	7.8	8 Dec	13 Dec	9.1		
Jan	20.3	9.9	15.1	28.3	-1.7	1 Jan	3 Jan	17.1	16 Feb	21 Feb
Feb	20.3	8.1	14.2	26.7	1.1	6 Feb	1,2 Feb	3.0		
Mean 119 days	21.1	13.3	17.2	31.7	-1.7	8 Dec	3 Jan	31.2		
1980										
Dec	22.4	12.7	17.5	28.3	4.4	12 Dec	1 Dec	4.0	18 Feb (2)	3-5 Mar (9)
Jan	21.6	16.0	18.9	26.7	1.1	11 Jan	6 Jan	1.0		
Feb	20.1	8.5	14.9	28.9	0.6	24 Feb	2 Feb	9.7		
First ½ Mar	24.6	11.6	18.1	30.6	-3.9	12 Mar	3 Mar	3.9		
Mean 106 days	21.8	12.3	17.1	30.6	-3.9	12 Mar	3 Mar	18.6		
1981										
Jan	16.5	4.9	10.8	23.9	-3.3	30 Jan	13,14 Jan	1.1	12 Feb	1-3 Mar (11)
Feb	22.9	11.6	17.3	27.8	1.1	22 Feb	4 Feb	9.0		
Mar	24.2	12.1	18.1	32.2	5.0	31 Mar	21 Mar	3.0		
Mean 90 days	21.1	9.5	15.3	32.2	-3.3	31 Mar	13,14 Jan	13.1		

[a] Actual or estimated. Number in parenthesis is number of nests.

114 of 2) in 121 nests where the completed clutch size was known. Nests with eggs were observed in the following counties: Alachua, 4 (I was with Stephen Nesbitt); DeSoto, 1; Highlands, 3 (I was with Fred Lohrer and James Layne); Indian River, 1; Okeechobee, 22; Osceola, 70; Polk, 34; and Glades, 1.

During 1970 a nest was found with 1 egg on 7 March. The 2nd egg was laid either 8 or 9 March. The 1st egg hatched 5 April and the 2nd on 6 April (incubation period of 28 or 29 days). Two eggs found 7 March 1974 hatched 30 days later on 5 and 6 April. In a nest found 1 March 1980 on Hayman Ranch, near Kenansville, Osceola County, the 2nd egg was laid 3 March and the eggs hatched 1-2 April, 30 days later. At a nest found 10 March 1980 in Polk County, the 2nd egg was laid either 11 or 12 March and both hatched 9 and 10 April, 29 days later.

I previously published weights and measurements of chicks (Walkinshaw 1976). They leave the nest within 24 hours after hatching. Eggs hatched in 92 (77.3%) of 119 nests followed through incubation. In these 119 nests, 224 eggs or chicks were observed; 176 hatched (78.5%) and 174 fledged (77.7%). Of the 2 chicks that did not survive, 1 was partly eaten by a predator and cause of death of the other was unknown. There were 82 nests where 2 chicks fledged and 10 where only 1 fledged. During 1979 a female was found dead in the water beside her nest yet the male hatched the 2 eggs. I did not know whether he raised the chicks. Among the 48 eggs that did not hatch, 4 were deserted (2 nests), 2 were broken by adults, 1 was infertile, and 41 were taken by predators. Apparently, the predators were raccoons (*Procyon lotor*) and feral hogs, the latter especially when pond waters receded.

Predation was severe during the dry years of 1971 and 1981. Rains came at the right time in 1977 and 1979 and water conditions were ideal. During 1978 there was too much water. I flew over ranches in Polk and Osceola Counties with the slowest plane available and it appeared that 25% of the land was under water. The ponds were too deep to wade and trails too wet for automobile travel. During 1976 (3 hours) and 1981 (4 hours), we covered northern Florida by helicopter, even flying over much of central Okeechobee County in 1976. Dr. James Layne was with me in 1976 and Dr. Miles Peelle in 1981. For the 1976 flight we thank the Florida Audubon Society and Major Realty, Inc. of Orlando.

THE RANCHES

The ownership of the Kissimmee Prairie has been very important in conservation of wildlife. During the 1930's cattle were on free range, there were no fences, and poaching was possible. Now all ranches are fenced, most gates are padlocked, and all ranches are posted against trespass. Hunting is carried on at a minimum in most regions. The ranch owners have proven to be the best conservationists in central Florida. But some ranches have had difficulties. The effects of property taxes, inheritance taxes, inflation, and the reduction in beef prices have been severe. Consequently some ranches have been sold to developers, some owners have sold portions of their ranches, and some have drained ponds to increase their usable acreage. The following has happened.

Osceola County

Alto Adams, Jr., Lake Marian Ranch, Kenansville (Fig.1).--This 12,146-ha ranch is still intact and managed much as it was in 1970. In 1976, twelve pairs of cranes and 3 nests were found; in 1977, nine pairs and 2 nests; in 1979, nine pairs, 2 nonbreeders, and 3 nests; in 1980, eight pairs, 2 nonbreeders, and 3 nests; and in 1981, only 4 pairs, 3 nonbreeders, and 1 nest. In 1970 I found 19 wetlands, several of which were less than 0.4 ha; in 1981 only 4 of these contained water.

W. Paul Hayman Ranch, Kenansville.--This 4,858-ha ranch has not changed much since 1970. In 1938 it was covered extensively with water. During the 1970's a ditch was extended from an earlier ditch so that 1 pond was drained completely. The Sunshine Parkway was built across the ranch and few borrow pits were dug; 1 of these has been used twice for crane nesting. (Ranchers could aid breeding cranes when they dig watering ponds if they extended them a little and made 1 end shallow. Shallow areas grow to emergent vegetation which produces adequate cover and the pits normally retain water even during droughts.) There have been 2 or 3 pairs nesting on this ranch since 1970. During 1981, three pairs and 2 nests were found. Part of the ranch is now rented to sodgrowers and this has been used by wintering greater sandhill cranes during several winters.

Three Lakes or Turkey Hammock Ranch along Lake Kissimmee.--This ranch was owned by the Padgett family in 1970. They sold a large portion to the Florida Fish and Game Commission and it is now a Wildlife Management Area. Portions of the north end of the ranch are not crane habitat but the

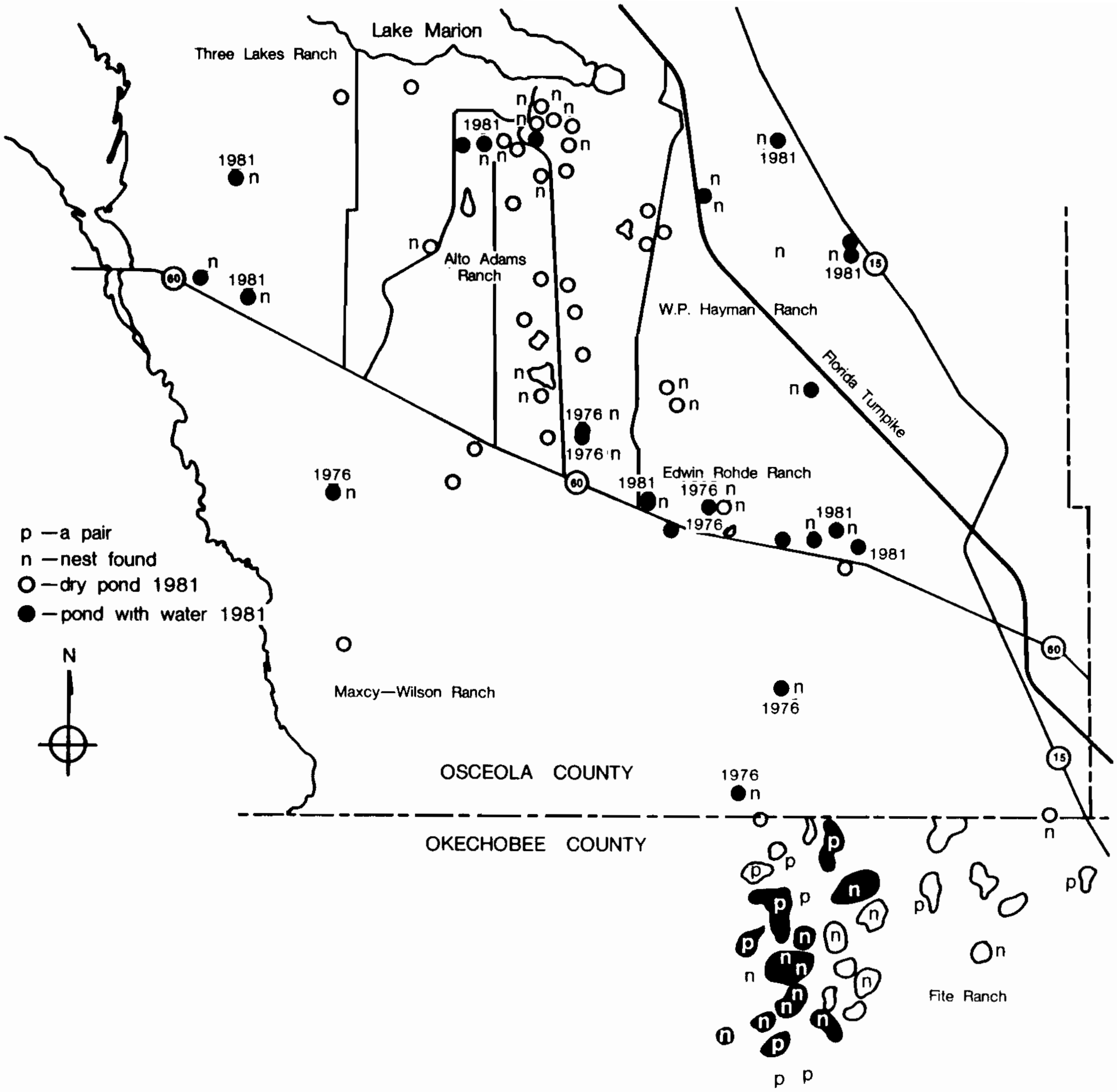

Fig. 1. Nest and pond locations in the main study area.

crane habitat south of there, including private land, totals about 7,287 ha. During 1976 we surveyed the entire ranch, even along Lake Kissimmee, without finding a crane nest; in 1981 we found 2 nests but saw only about 8 wetlands with water. According to neighboring ranchers, much wildlife was destroyed when the Wildlife Management Area opened to hunting during the 1970's.

Maxcy-Wilson Ranch, Yeehaw Junction.--This immense ranch of more than 42,500 ha has not changed since 1970 except in ownership. Pat Wilson is the present owner. The ranch extends from the Kissimmee River to Highway 441, west to east, and from Highway 60 on the north to the Okeechobee County line on the south. Some of the higher land has been converted to orange groves, some has been leased to tomato growers, and some has been changed to sod farming, but much of it is still used for cattle grazing. During 1976 we surveyed much of the ranch by helicopter and found about 12 wetlands. We only located 3 nests but there could be as many as 25 pairs of cranes.

LeRoy Bass-Edwin Rohde Ranch, Yeehaw Junction.--This ranch had much water and many cranes in 1938; 6 pairs and 3 nests in 1976; 4 pairs in 1977; 4 pairs and 1 nest in 1979; 4 pairs, 2 nonbreeders, and 1 nest in 1980; and 4 pairs, 3 nonbreeders, and 3 nests in 1981. Ditches have not been built recently but an existing ditch was deepened. When the Basses died the ranch was inherited by the Rohdes. To pay inheritance taxes, they sold much of the pine forest and rented a large portion to tomato growers. The original ranch contained 7,288 ha, but it is split into 3 ranches. The Rohdes own the largest portion (5,688 ha). There were only 5 wetlands with water in 1981.

Okeechobee County

The Harris Ranch, Yeehaw Junction.--The original Harris Ranch consisted of 10,883 ha. Sand roads crossed from the northeast to the southwest and 1 from the center to the northwest. Pete Fite bought the ranch in 1972 but sold it in 1979-1980. Now it is owned by 4 parties. Alto Adams, Jr. bought the 9 sections in the northwest corner, the Nature Conservancy purchased 9 sections in the southwest corner, a Mr. Harvey bought about the same amount in the northern section, and the remainder was purchased by Lefty Durando.

The Nature Conservancy turned their land over to the National Audubon Society. During 1976 Pete Fite constructed a ditch across the west-southwest portion which drained at least 13 ponds, many of which had been used for crane nesting. But the ditch was not connected to any other so that it deposited water at its lower level in greater amounts than previously, benefiting the southwest region. Twelve wetlands were observed in 1981 on the entire region and 1 nest was found. Five pairs of cranes and 8 nonbreeders were also observed.

Polk County

The W. D. Crews Ranch, Lake Wales.--Owned jointly by W. D. Crews, Sr. and Jr., this ranch, that is mostly cattle pastured prairie, contains 1,822 ha. One ditch was extended across the southern portion in 1979. There were 5 usable wetlands during 1979 and 1980; these were all dry during 1981. This is 1 of the few ranches found on the ridge, at an elevation of 35.7 to 36.6 m. One nest was found during 1979 and 1 in 1980. One pair of cranes and 3 nonbreeders were present in 1981.

Lake Kissimmee State Park.--The park (2,035 ha) contains 283 to 404 ha of crane habitat and 1 or 2 breeding cranes between Lakes Kissimmee and Rosalie. A pair with a chick was seen near the park entrance in March 1979. A flock of 160 greater sandhill cranes wintered there in 1979-1980 (1 bird wore a streamer with number 124 on both wings; the streamer was attached in Wisconsin). This flock roosted at night in a large wetland in the northwest sector of the park. They returned in October 1980 but left during the dry 1980-81 winter. The main wetlands extend along the shores of the lakes.

Sam Keen Ranch.--Owned by Gulf American Corporation for purposes of development, this ranch consists of 6,073 ha and much of it is still grazed by cattle. There is considerable hunting on the ranch. Three pairs of cranes nested there in 1979 and 2 pairs in 1980. No active nest was found when we surveyed the ranch by helicopter in 1981. Five wetlands were present and 4 of these had previously been used for nesting.

Roy Keen Ranch.--There are about 688 ha of cattle pasture used by cranes on this ranch east of Lake Wales. The only nest was found there in 1971. Since then the nesting pond has been dry. Normally there are 3 wetlands on the ranch but all were dry in 1981.

Paul Keen Ranch.--Now owned mostly by Gulf American Corporation, the ranch consists of 6,073 ha of which 2,073 ha is cattle-pastured prairie containing 5 wetlands. Two crane pairs and 1 nest were found there in 1981 during the helicopter survey.

The Peters Ranch.--Now owned by Gulf American Corporation, it consists of approximately 1,036 ha on which there are still 3 wetlands. A pair of cranes nested there in 1979 and in 1981. We surveyed it by helicopter in 1981.

River Ranch Acres (48 km east of Lake Wales).--Owned by Gulf American Corporation, the 22,041 ha have been subdivided into 0.1-ha lots. The ranch is still pastured by cattle because few houses have been built. At least 5 paris of cranes nested there during 1967 and 1968 and flocks of nonbreeders were present. Two of the nest ponds have been drained since 1968 and another has been lost to approaching developments. One pond should still be present on the edge of the Avon Park Bombing Range.

CONCLUSION

Prairie country of central Florida (Okeechobee, Osceola, and Polk Counties) is slowly disappearing because of changing land use, drainage of ponds, and development. During the 1981 nesting season, even with a helicopter and much work on foot, Hoke Fitzgerald, Jr., Miles Peelle, and I found only 28 pairs, 11 nests, and 17 nonbreeding cranes on 12 properties totaling 81,630 ha. This habitat has been the greatest stronghold of the species. As the prairie country disappears, so does the central Florida crane population.

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BREEDING ECOLOGY OF THE MISSISSIPPI SANDHILL CRANE IN JACKSON COUNTY, MISSISSIPPI

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Abstract: Data on Mississippi sandhill crane (*Grus canadensis pulla*) reproduction and nesting habitat characteristics were collected in Jackson County, Mississippi, from 1965 through 1981. Eighty-three nests were found. The largest number of nests found in a season was 8 (1968); 7 were found in both 1971 and 1977. Only 2 were found in 1980, but 5 were found in 1981. Eleven general breeding areas containing 20 territories were identified. Nine territories appear to be permanently abandoned and 3 others may be. I estimate there are presently 8 to 10 breeding pairs with a total population of 30 wild cranes plus 9 captive-reared released cranes. The earliest hatching date was 18 April and the latest 21 June. The peak of hatching occurred during 1-20 May when 70% hatched. Nests were found in 4 habitat types: open savanna (47%), swamp edge (36%), pine plantation (11%), and pine forest edge (6%). The overstory cover was measured on 0.28-ha circular plots (N = 18) surrounding nests. Tree and brush cover ranged from 5 to 26% of the area within swamp edge, 5 to 19% within pine plantations, and 1 to 8% within savannas. The shortest distance between active nests was 715 m. Three nests were only 715 to 833 m apart in 1971. The hatching success of 78 wild eggs was 64% compared to 65% of 49 eggs incubated in captivity. The mean size for 79 completed clutches was 1.86 eggs. Crows destroyed 4 eggs from 3 clutches.

The Mississippi sandhill crane was listed as endangered by the Department of Interior in 1973, after being described as a new subspecies by Aldrich (1972). Early reports include Leopold (unpubl. 1929), McIlhenny (1938), Turcotte (1947), and Walkinshaw (1949, 1960). Life history and the environment were described by Valentine and Noble (1970). Valentine and Noble (1976) wrote of the threats to the crane, the problems created by the construction of Interstate Highway 10, the federal court case, and the need for a refuge. A status update on the crane, the outcome of the litigation, and the establishment of the Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR) were described by Valentine (1979). A Recovery Plan (1976) was approved by the Fish and Wildlife Service (FWS) and revised in 1979 (Valentine et al. 1979).

This paper summarizes 18 years of field work that began when I was assigned to evaluate the effect of the proposed I-10 highway on the crane (Valentine 1963 report in FWS files), and continued with the plan to reintroduce sandhills into Louisiana (Valentine 1964 report in FWS files). The objective was to establish a captive flock of cranes whose progeny would be released into the wild. Searches for nests in Jackson County, Mississippi, began in 1965 and have continued through 1981. Eggs were collected for captive propagation from 1965 through 1977 and again in 1981. No formal study plan was made; most of the data were collected incidental to collection of eggs, service on the Recovery Team, and establishment of the refuge.

I thank the many volunteers who have assisted in nest searches; J. D. Schroer, G. Heet, and B. A. Grabill and the staff of the MSCNWR; and the Mississippi Department of Wildlife Conservation, particularly R. E. Noble, L. Strong, and W. H. Turcotte, for assistance and support. The Patuxent Wildlife Research Center staff, especially R. Erickson and J. J. Lynch (both FWS retired), are thanked for many years of cooperation in the captive propagation work. Special thanks are due to C. L. Cordes and J. W. Kurth (both FWS) for assistance in field work and analysis of data relating to characteristics of nest sites.

STUDY AREA

The study occurred within the entire range (41,000 ha) of the Mississippi sandhill crane in southern Jackson County, Mississippi. The west boundary of the breeding range is the Jackson County line and the east is the West Pascagoula River. Nesting begins 5 km from the Gulf of Mexico and extends 19 km north. The area, topography, geology, soils, plant communities, and nesting habitats have been described by Valentine and Noble (1970) and Valentine (1981). In the early years of the study all of the cranes were found on private lands that were primarily owned by timber companies. Most of the nesting habitats are now located on the MSCNWR, established in 1974, which now includes about 6,800 ha. The crane population probably has always varied with land use and been small because of the limited habitat. My population estimate in 1978 (Valentine 1981) was between 40 and 50, but I now believe there may be as few as 30 (plus 9 released), including 8 to 10 breeding pairs.

METHODS

Searches for nests were conducted mainly by 1 or more persons walking through forests and savannas that appeared to be suitable nesting habitat. The nests were found when the crane flushed from the nest. When disturbed by the searchers, the cranes flushed at distances of 8 to 400 m (mean 56 m, N = 55). After several eggs had been cracked by the cranes taking flight, we began clapping our hands or making other noises to give the cranes plenty of time to anticipate our approach. With experience and knowledge of the area, we concentrated our efforts in places that had previously contained nests. A total of 1,128 walking man-hours were spent finding 76 active nests, or about 15 hours per nest. Seven nests were found in 20 hours of helicopter time; no nests were located in 3 hours of flight in a light plane. Walking search-time per season varied from 15 man-hours in 1972 when 5 nests were found, to 121 hours in 1981 when 5 nests were also found. The annual average search-time for 18 years was 66 man-hours. The most efficient and economical use of time and effort was when 1 or 2 experienced persons searched on foot. Aerial surveys were costly and dense brush and tree cover made it difficult to find nests.

Nests were visited with some regularity several times during the season. The main purpose of nest searches was to remove for captive propagation 1 egg from each 2-egg clutch. When I believed all of the nests had been found for that season, the eggs were collected in 1 day, placed in heated containers, and transported to a propagation station. Measurements were made of the nests, eggs, water depth, and distances from other nests. The nest locations were marked on aerial photographs. Hatching dates and success data were collected opportunely.

The space occupied by brush and trees within a circular plot (0.28 ha) was measured in order to assess characteristics of the overstory. Eighteen nests were studied during 1974 through 1980. Each nest was the center of a circle with a radius of 30 m. Species, height, and diameter were recorded for each tree and shrub within the plot. Tree diameter was measured at breast height (dbh). The width of the area covered by shrubs and trees was the boundary of the maximum extension of branches. The percent brush cover within 8 m of the nest was computed separately from the total cover. Nomenclature of plants follows Radford et al. (1964).

RESULTS

Nesting Habitats

Walkinshaw (1949:146) commented on the ideal nesting conditions maintained in the study area in 1940 by the prevailing turpentining and light lumbering land use. He stated that the cranes nested in areas less open than any other crane habitat he had seen, but cautioned that if the pines were left uncut they would cover the open areas. I predicted in 1963 (report in FWS files) that the cranes would be extirpated because of increasing cover resulting from the planting of pine trees, drainage of wet areas, and fire prevention. Some territories have become too overgrown for nesting, but others have remained relatively open because of the slow pine growth in wet situations, and partly because of fires.

Cranes in their North American distribution show a predilection for nesting in open shallow lakes and marshes, a preference which may be related to territoriality, food needs, and escape from predators. The Mississippi sandhills may have accommodated to the intrusion of woody cover because of the lack of predators. The small openings surrounded by forests also provide a great degree of isolation.

Except when disturbed, Mississippi cranes are ground-living birds that walk to and from the nests to feed or to take their turn at incubating eggs. One or more well-defined trails radiated out from virtually all of the nests. With the exception of man and dogs there are few animals that would flush a crane from the nest.

There are 4 general nesting habitat types: open savannas, swamp edges, pine plantations, and pine forest edges. The ground cover, essentially the same in all types, is composed of grasses, sedges, and an array of wet-acid-soil plants. I consider nut-rush (*Scleria baldwinii*) as the indicator plant for nesting sites. Among 83 nests, 30 (47%) were found in open savannas, 30 (36%) along swamp edges, 9 (11%) in pine plantations, and 5 (6%) along pine forest edges.

Measurement of woody vegetation surrounding the nest provides an index of the possible limits of tree and shrub density that cranes will tolerate (Table 1). The percent cover was greatest along swamp edges and ranged between 5 and 35% (mean 17%, N = 5); cover in pine plantations ranged from 5 to 19% (mean 10%, N = 4), and in unplanted savannas ranged from 1 to 8% (mean 4%, N = 10). The percent of shrub overstory, which was considered visually more obstructive to cranes, within 8 m of the nest ranged from 0 to 19% (mean 5%) in swamp edges, 0 to 5% (mean 2%) in pine plantations, and 1 to 5% (mean 1%) in savannas. The shrub cover within 30 m of the nest ranged from a

Table 1. Total number of trees and shrubs in the overstory cover and the spacial area occupied by them within 0.28-ha circular plots surrounding 18 Mississippi sandhill crane nests. (Small trees = <3 cm diameter breast height; large = >3 cm dbh; cover <8 m = within 8 m of the nest.)

	Number of trees			Number of shrubs				
Habitat and nest code no.	N small <3 cm	N large >3 cm	Cover area (m^2)	N	% cover <8 m	Cover area (m^2)	Total cover (m^2)	% cover
Swamp edge								
4-74	57	211	735	117	0	233	968	35
3-77	173	78	437	50	19	291	728	25
4-76	7	50	198	49	6	88	286	10
1-80	48	62	171	21	0	49	220	8
4-79	8	31	91	19	0	48	139	5
Pine plantation								
2-80	335	115	395	49	2	147	542	19
4-78	0	0	0	49	3	237	237	8
3-79	212	0	62	22	0	148	210	7
2-79	167	5	57	59	5	97	154	5
Savanna								
4-75	15	10	46	66	5	164	210	7
2-77	120	27	145	47	1	59	204	7
5-74	233	26	87	11	4	53	140	5
4-77	1	15	27	15	1	122	149	5
1-79	6	16	82	18	1	62	144	5
1-77	52	14	35	28	1	53	88	3
1-76	69	13	40	19	1	27	67	2
5-77	0	3	28	26	1	30	58	1
5-78	0	0	0	14	1	12	12	1

trace to 10% (mean 4%). In 15 of the 18 plots, the area within 8 m of the nest contained less brush per area than did the total area.

Gallberry (*Ilex glabra*) was the dominant shrub species in 3 nesting habitats (Table 2), ranging from 38 to 63% (mean 44%). Wax myrtle (*Myrica cerifera*), black gum (*Nyssa sylvatica*), and yaupon (*Ilex vomitoria*) each averaged about 15% of all shrubs. Gallberry averaged 1.5 m in height with a crown diameter of 1.8 m. Wax myrtle averaged 1.8 m in height and a diameter of 1.8 m. Black gum averaged 2.4 m in height and 1.5 m in diameter, and yaupon averaged 2.0 m in height and 1.9 m in diameter. Gallberry bushes were most numerous in the pine plantations, which may be a consequence of site preparation. Gallberry appears to flourish in abandoned croplands and pastures.

The number of individual shrubs within the 0.28-ha plots was greatest in the pine plantations (range 49 to 62, mean 54). In the swamp edge the number ranged from 19 to 117 with a mean of 51. The smallest number was in the savannas (range 11 to 66, mean 27). The area of brush cover in the pine plantations ranged from 97 to 237 m^2 (mean 157 m^2). The brush cover in the swamp edge ranged from 48 to 291 m^2 (mean 142 m^2). Brush cover was least in the savannas and ranged from 12 to 164 m^2 (mean 65 m^2).

Savanna (Table 3) was 93% slash pine (*Pinus elliottii*) and 7% longleaf pine (*Pinus palustris*). Swamp edge was 64% slash pine, 30% pond cypress (*Taxodium ascendens*), and 6% longleaf pine. Only slash pine was found in the pine plantations. The mean dbh of large slash pine was 9 cm and the mean height was 5.6 m (N = 366). Small slash pine (<3 cm dbh) averaged 2.4 m in height (N = 996). The mean dbh of large longleaf pine was 12.7 cm and the mean height was 9.5 m (N = 29). The mean dbh of large pond cypress was 8.9 cm and the mean height was 6.7 m (N = 102); small cypress averaged 2 m in height (N = 73).

The slash pines were stunted because of poor habitat conditions. Most had been planted, but there was also some natural regeneration. The long-leaf pine which was indigenous was found mainly along the edges of the swamp or were old widely disbursed relicts standing in the large savannas.

The ground cover usually consisted of dense low-growing plants. Eleuterius and Jones (1969) listed over 250 species of plants growing in pitcher plant bogs in neighboring Harrison County.

Table 2. Shrub species in savanna, swamp edge, and pine plantations within the 0.28-ha circular plots (N = 18) surrounding Mississippi sandhill crane nests.

	Gallberry	Wax myrtle	Black gum	Yaupon	Sweet bay	Others
Savanna (N = 9)						
No. shrubs	99	57	52	12	34	7
% all shrubs	38	22	20	5	13	3
Swamp edge (N = 5)						
No. shrubs	84	18	48	49	3	15
% all shrubs	39	8	22	23	1	7
Pine plantation (N = 5)						
No. shrubs	108	22	0	30	6	5
% all shrubs	63	13	0	18	3	3
Total	291	97	100	91	43	27
%	45	15	15	14	7	5

Most common were species of Lycopodiaceae, Poaceae, Cyperaceae, Xyridaceae, Eriocaulaceae, Liliaceae, Haemodoraceae, Orchidaceae, Sarraceniaceae, Droseraceae, Polygalaceae, Hypericaceae, Melastomaceae, Lentibulariaceae, and Asteraceae.

Nesting Areas and Territories

Twenty territories were identified within 11 areas. A nesting area was the general location of 1 or more territories which were more or less contiguous. A territory was defined as the locale where a pair habitually built their nests. An area and a territory were synonymous in 7 instances.

Table 3. Tree species in savanna, swamp edge, and pine plantations within the 0.28-ha circular plots (N = 18) surrounding Mississippi sandhill crane nests.

	Slash pine		Longleaf pine		Pond cypress	
	<3 cm dbh	>3 cm dbh	<3 cm dbh	>3 cm dbh	<3 cm dbh	>3 cm dbh
Savanna (N = 9)						
No. trees	514	69	2	4	0	0
% all trees	82	11	tr	6	0	0
Swamp edge (N = 5)						
No. trees	124	222	7	27	73	87
% all trees	23	41	1	5	14	16
Pine plantation (N = 4)						
No. trees	547	125	0	0	0	0
% all trees	81	19	0	0	0	0
Total trees	1,185	416	9	68	73	87
% all trees	64	23	tr	4	4	5

The greatest distance between nesting areas was 25 km and the shortest distance 2.5 km. Eighty-three nests were found from 1965 through the spring of 1981. The largest number of nests found in 1 season was 8, 7 were found both in 1971 and 1977, only 2 in 1980, but 5 in 1981 (Table 4).

Nests have not been found on 9 territories since 1974, nor on 3 others since 1978. A nest was found on 1 territory for 10 years in succession, but none since 1977. Another territory held 10 nests over a period of 15 years, but none in 1981, probably because of a late winter fire that burned the site. There have been gaps of 4 (1973-1976), 5 (1976-1980), and 6 (1975-1980) years between nesting on a particular territory. In the latter instance, the territory had been opened up by hand-clearing of pine trees, and a fire may have forced the pair to move from a nearby territory.

Some assumed causes for abandonment of territories were dense growth of trees and shrubs, highway and road construction, wildfires, and the death of 1 or both members of the pair. The absence of a nest for some years on formerly used territories may be a consequence of our failure to discover a nest despite intensive searches. Another explanation might be that the 1st pairing was broken, or they had deserted the territory, and in subsequent years another pair moved in. In 1981, we located 9 pairs on or near traditional territories, but found only 5 nests, 1 of which was a 2nd attempt. The presence of a pair without a nest suggests that we may not be finding all of the nests or that some cranes do not nest each year.

I found only 12 instances (renestings not included) in 83 nests where more than 1 active nest was found in the same nesting area during the same year (Table 5). Walkinshaw (1960:42) in 1940 found 2 active nests 152 m apart. The shortest distance between 2 nests in this study was 715 m. In 1971, 3 nests were only 715 to 833 m apart along the edge of a swamp. All individual territories were buffered by wide corridors of trees and brush. Only 1 nest was found in a given season in any 1 of the large open savannas. I presume the large size and spacing of the territories are mainly functions of the small crane population. In small savannas surrounded by brush and trees, the year's nests were close together; however, in large open savannas they were widely spaced.

Nests and Nesting

Most sandhill crane subspecies in North America build their nests in shallow water. The Cuban crane (*G. c. nesiotes*) prefers dry ground (Walkinshaw 1953) and the lesser sandhill (*G. c. canadensis*) on Banks Island, Northwest Territories, builds a nest of small proportions on nearly bare sand dunes (Walkinshaw 1965a).

Water at the nest sites in Mississippi ranged from none to 30 cm in depth. Among 77 nest sites, 38 (49%) were dry on the initial visit, 10 (13%) were moist, and 29 (38%) were wet. During wet springs (1973 through 1975), all nests (13) were surrounded by water. Early in the season many nests were in water, but as the season progressed the water disappeared. A few nests that were in dry sites were later flooded during heavy rains. Only those territories on the edges of swamps held relatively permanent standing water. I found no reduction in nesting during droughts, but chick survival may have been adversely affected. During some droughts, standing water was found only in widely separated roadside ditches or in swamp watercourses, and even these occasionally dried.

Mississippi crane nests varied from token piles of grass, laid on top of grasses or sedges, to large structures. They are roughly circular to oblong. Nests in water tended to be large while the smallest were on dry sites. The largest nest by volume (160 X 120 X 35 cm) was found in a moist site and the smallest (45 X 45 X 3 cm) was in a dry site. The mean size of 30 nests was 104 X 83 X 11 cm.

An attempt was not made to thoroughly catalog the variety of material used in building the nest. The nests were composed mainly of stems, leaves, and root material of the plants growing nearby. The nest was usually laid directly on growing vegetation but sometimes on a low stump or raised tussock. Soil was also added to the plant material. Material was added to the nest during and after rainstorms, but the process looked perfunctory and did not always protect the eggs from flooding. Sometimes as many as 5 or more freshly built "start" or "dummy" nests were found near the active nest.

In at least 5 instances, nests were used for than 1 season. One nest was active 3 years in a row; another was used 1 year, vacant the next year, but occupied again the 3rd year. Three other nests were occupied for 2 consecutive seasons.

Fire ants (*Solenopsis invicta*) often occupied active nests and, when the nest was disturbed by humans, the ants would swarm over the nest and even on emerging chicks. The ants apparently tolerated the incubating crane, and chick deaths or injuries were not observed from ant stings.

Table 4. History of 20 nesting territories in Jackson County, Mississippi, 1965 through 1981. An X indicates when a nest was found; XX denotes 2 nests, the result of renesting.

Territory name	1965-1976	1977	1978	1979	1980	1981	Total
Browns 1A	2						2
Browns 1B	5	XX	X	X	X	X	11
Browns 2	8					X	9
Williams 3	1						1
Williams 4	6	X	X	X	X		10
Williams 5	3						3
Williams 6	3						3
Perigal 7A	3						3
Perigal 7B	2						2
Perigal 8A	3						3
Perigal 8B	2						2
Simms 9	3						3
Simms 10	1						1
Ft. Bayou 11	2						2
Bourne 12	9	X					10
Eglin Road 13	4	X	X			XX	8
Vickers 15	2	X		X			4
St. Regis 16	1					X	2
Weber 19		X	X				2
Mallette 20			X	X			2
Totals	60	7	5	4	2	5	83

Table 5. Distances between crane nests in adjacent territories during the same year, Jackson County, Mississippi. Renesting attempts are not included.

Nest numbers	Territories	Distance apart (m)
6-71, 7-71	Williams 5, Williams 6	715
3-71, 6-71	Williams 4, Williams 5	833
1-66, 4-66	Browns 1A, Browns 2	722
3-74, 4-74	Williams 4, Williams 5	856
4-67, 5-67	Simms 9, Simms 10	895
3-69, 4-69	Browns 2, Browns 1B	1,257
2-75, 3-75	Williams 6, Williams 4	1,343
3-72, 4-72	Browns 2, Browns 1B	1,351
1-81, 3-81	Browns 1B, Browns 2	1,414
3-76, 4-76	Williams 4, Williams 6	1,516
2-74, 5-74	Browns 2, Browns 1B	1,657
2-67, 3-67	Perigalt 8, Perigalt 7	1,673
2-66, 3-66	Perigalt 7, Perigalt 8	1,673

Habitat Destruction and Disturbance

The Mississippi crane generally nested as far as possible from sources of disturbance. In earlier times, lumbering, turpentining, and grazing brought people and livestock into the breeding areas. During the 1950's and 1960's pine tree planting was in full swing in most open savannas and the crews reported finding nests. Many miles of access roads were built at that time by the timber companies, often bisecting savannas. With the economic and population growth on the Gulf Coast, thousands of acres of habitat were destroyed or made uninhabitable by housing and commercial developments, small farms, and other individual residences. Recently, there has been less disturbance during the breeding season, but some spring turkey hunting occurred in the northern part of the breeding range. Incendiary fires and wildfires, usually occurring in the winter and early spring months, have destroyed nesting territories.

Howard (1977:41) in Wisconsin measured the distance from nests to sources of human activity to get an index to the seclusion required by nesting cranes. He defined human activity as the operations around buildings and cranberry marshes, but apparently did not include roads and other disturbances. This distance ranged from 305 to 5,630 m and averaged 1,714 m. Mississippi cranes have a difficult time getting away from some source of disturbance. Visual and noise disturbances from vehicular traffic and highway construction created the greatest problem. The distance from the nest to a disturbance factor ranged from 63 to 1,200 m.

Interstate Highway 10 was built directly through the breeding range. The right of way and the excavation of roadbed fill removed 340 ha from the crane habitats and a borrow pit destroyed an active territory. The pair moved 600 m from the highway, but deserted the area after 2 years. Another territory located 500 m from the highway, but isolated by forest, remained active throughout construction and opening of the highway. Cranes nested on 2 occasions within 80 m of county highways with moderate traffic; again the nests were well hidden by dense pine. Two other nests were located 63 and 94 m from a little-used vehicular trail. Nests have been found 320 to 510 m from a large subdivision. Nests have not been found in open savannas adjacent to highways. Intrusions by man were minimal in all regularly used territories because there was little to attract people into the area, and forests insulated the nests from traffic noise and movements.

Eggs and Incubation

The mean size of 79 completed clutches was 1.86 eggs. The mean length of 40 eggs was 94 cm (91-105 cm) and the mean diameter was 59 cm (54-68 cm). Walkinshaw (1965a:142) gave measurements of 172 eggs from Michigan as 94 cm (86-108 cm) X 60.6 cm (54-66 cm). Three eggs were found on the day of laying and were followed through to hatching, either in the wild or in captivity. The incubation period for a successful hatch was 30 days including the day of laying, but not including the day of hatching. The longest period of incubation was at least 52 days at a nest found on 18 April 1979. A rotten egg was removed from the nest on 25 May but the cranes continued to incubate until 8 June when the remaining addled egg was removed. Another pair incubated at least 34 days after their nest was found before abandoning the rotten egg (1 had been removed earlier). The latest incubation date without hatching was 27 July 1977 (a renesting).

Phenology

The nesting season for Mississippi cranes is relatively late compared to the Florida subspecies, and also to Michigan and Wisconsin greater sandhills when allowance is made for the difference in latitude. The hatching dates for 69 eggs in central Florida ranged between 15 February and 21 April, with the average date 25-26 March (Walkinshaw 1976:8). Howard (1977) found hatching in Wisconsin ranged from 17 May to 17 June, with 70% of the eggs hatching from 19 May to 30 May. I determined that the peak of hatching occurred 1-20 May in southern Michigan by using Walkinshaw's 1965b:140) data for 40 eggs. My data for Mississippi showed the peak during 1 May through 20 May when 69% of 49 observed clutches hatched; 12% hatched between 18 and 30 April and 18% between 21 May and 21 June (Fig. 1). The earliest calculated laying date was 19 March 1977, with hatching on 18 April. The latest hatching date for an egg (considered a 2nd attempt) was 21 June 1966. The companion egg had been removed and hatched at the J. J. Lynch aviary on 19 June.

Cranes from the Okefenokee Swamp, Georgia, located at about 31 N latitude, nest earlier than Jackson County cranes. Six eggs collected from Okefenokee National Wildlife Refuge hatched between 15 and 29 April at Patuxent (S. Derrickson pers. comm.) and 9 nests were found during 27 February and 12 March 1973, with hatching in March and early April (J. Eadie pers. comm.). Three hatching dates about 20 April 1951 (Walkinshaw 1953:9) and another on 20 May 1904 (Walkinshaw 1949:102) indicate that the Cuban crane is a late nester. Walkinshaw (1949:102) speculated that the reason the Cuban sandhill nests later than the Florida sandhill is because March and April are usually dry in Cuba.

When the Mississippi cranes begin to nest, the grasses, sedges, and forbs are in their dry winter aspect and barely 20 cm tall. During the incubation period pitcher plants (*Sarracenia* spp.), snake-mouth orchid (*Pogonia ophioglossoides*), grass pink (*Calopogon pulchellus*), and fly-poison (*Amianthium muscaetoxicum*) come into flower and peak. About hatching time, goldencrest (*Lophiola americana*) and meadow beauty (*Rhexia alifanus*) begin flowering, and red-root (*Lachnanthes caroliniana*) begins to flower when the last eggs have hatched. My observations indicate that the Jackson County crane range (located about 30°30' N latitude) is phenologically about 2 weeks behind Lafayette, Louisiana (at about 33°15' N latitude). The cooling effect of the Gulf of Mexico during the spring may account for the lateness of the nesting season in Mississippi cranes.

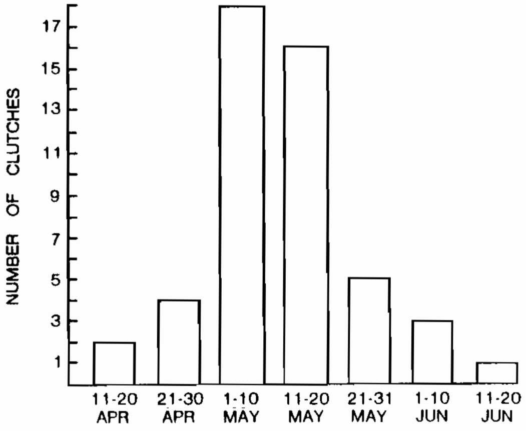

Fig. 1. Hatching chronology of Mississippi sandhill crane eggs for years 1940 through 1981 based on 49 clutches in captivity and wild. Two early records from Walkinshaw (1960) and Gandy and Turcotte (1970).

Presence at the Nest

One crane was present at the nest during 91% of our visits (N = 197); 2 cranes were in attendance 29% of the time. On rare occasions, 3 birds were seen fairly close to the nest. When cranes were not present at the nest, the eggs were either rotten, cracked, destroyed by crows, or abandoned. Occasionally cranes were near the nest but the eggs were gone, so I assumed that chicks were in the immediate area.

Hatching Success

Hatching success of 78 wild eggs was 64% (through 1981) compared to 65% of 49 eggs incubated in captivity (through 1977). Twenty-eight eggs from 23 sets failed to hatch (through 1981). Nine eggs (6 sets) were addled because of infertility or other reasons, but were being incubated. Seven nests were deserted (2 contained cracked eggs, 1 had punctured eggs, 4 were deserted for unknown reasons). The incubating cranes cracked 4 eggs while rising from the nest after being disturbed by humans. At least 3 eggs were missing from nests and may have been taken by predators or humans. Some eggs absent from the nest may have hatched but these were not included in my data. Crows destroyed 4 eggs in 3 clutches. In 2 of these clutches (3 eggs), the crows found the eggs while the cranes were off the nest because of disturbance by nest searchers. This destruction should be considered scavenging rather than predation. A sanitary fill dump, now closed, attracted large numbers of crows to the area in the 1970's. One egg was believed pecked by 1 of the cranes soon after their nest was found. The puncture was large and none of the contents had been eaten. Only 9 of 28 eggs that did not hatch could have been infertile, which belies an earlier assumption (R. Erickson, pers. comm.) based on captive incubation data, that Mississippi crane eggs were less fertile than other subspecies.

Renesting

Three nests were found that indicated that renesting occurred after the 1st clutches were removed or failed to hatch. In all such instances, the new nests were located less than 100 m from the nest that held eggs earlier. I suspect that 2nd clutches are more common than this study indicates. I rarely searched for nests after I had collected the eggs for captive propagation, so 2nd nesting attempts were found only accidentally. In 1981, I made a deliberate search for renesting in an area where the cranes had destroyed their 1st egg, and I found a 2nd nest with 2 eggs. The 2nd clutch was laid about 15 days after the 1st clutch had been abandoned.

Chicks and Recruitment

I observed 10 chicks on the nest and all were apparently healthy and free from debilities. In 1-chick broods, the chick remained at the nest from 1 to 3 days. In 2-chick broods, the stay at the nest was 2 or 3 days for the oldest and 1 day for the youngest. Chicks were not seen after they left the nest and only a few nonfledged young were observed. Little time was spent in determining recruitment beyond the chick stage. I was shown (S. Derrickson, pers. comm.) how to recognize subadults and was able to find only 1 bird of the year among an estimated 15 individuals during the winter of 1980-1981.

CONCLUSIONS

I believe I can say with some assurance that the population of cranes in Jackson County is smaller in 1981 than it was in the 1960's and into the 1970's. I can only speculate on the causes, but the controversy relating to the construction of I-10 created adverse publicity and enmity toward the crane that may have inspired lawless persons to kill some cranes in the wintering grounds. Fires by arsonists increased dramatically in the late 1970's. The loss of 1 or 2 birds per year may exceed recruitment.

The Recovery Plan (Valentine et al. 1979) recommends that the MSCNWR be completed. Except for a number of small tracts the acquisition has been done. There are 2 main goals in breeding hatitat improvement: reduction of trees and shrubs and the improvement of the water economy. Habitat management to increase and improve nesting sites includes the harvesting of timber, hand-cutting of small pine trees, prescribed burning, creation or retention of tree and shrub buffers between actual territories and improved nesting sites, and planting or encouraging forest growth along federal and state highways. Runoff of rainfall will be retarded by plugging drainage and roadside ditches and the construction of 5 water control structures set into raised roads or trails. All of these practices have been completed or are in progress.

Although a number of formerly used territories have been abandoned because of dense cover, there appears to be an adequate number of potential or actual nesting sites to satisfy needs of the present population. The rehabilitation of savannas and other openings on MSCNWR should provide sufficient nesting habitats to provide for an increasing population. Nine cranes raised in captivity were released in the refuge in February 1981 and to date (after 8 months) the release has been a success with no mortality. Additional releases will continue for several years. The prognosis is that with a larger captive breeding flock and improved propagation techniques the yearly production for releases will increase and, along with natural wild recruitment, the Mississippi crane population will increase. The population goal for recovery is 80 to 100 cranes.

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MIGRATION ECOLOGY OF SANDHILL CRANES: A REVIEW

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Abstract: This paper summarizes our present understanding of sandhill crane (*Grus canadensis*) migration and presents a general model of spring and fall migration between breeding and wintering areas based on movements between and utilization of staging areas, traditional stopover areas, and nontraditional stopover areas. Management considerations resulting from an understanding of this model are discussed. Sandhill cranes are opportunistic in their selection of nightly roosts at nontraditional stopovers. Under suitable conditions migratory flights generally begin 1.5 to 5.5 hours after sunrise and continue until 2 hours before to 0.25 hour after sunset. Documented daily flights are variable in length and have ranged from 48 to at least 740 km and lasted for periods of 1 to over 10 hours. Ground speeds vary from 22.5 to 82.6 km per hour and are determined primarily by wind speed and direction. The total distance of each migratory flight is determined by 2 factors: average ground speed and the length of time the cranes choose to be airborne. Three types of flight behavior are exhibited: flapping, spiralling, and gliding. Available evidence indicates that the bulk of migration occurs within 1,600 m of the ground. Sandhill cranes are primarily diurnal migrants, although migratory flights occasionally continue after dark. The effects of weather and behavioral stimuli on sandhill crane migration are discussed, as are relationships between hunting and migration.

INTRODUCTION

Migration by sandhill cranes can be defined as traditional movements made each spring and fall between areas used for nesting and fledging young and locales used for wintering. Some sandhill crane populations spend 4 months or more each year in migration, navigating thousands of kilometers each spring and fall over relatively unfamiliar terrain between breeding and wintering areas. These semiannual migrations represent important periods in the annual life cycles of sandhill cranes because they require considerable investments in time and energy, as well as special direction-finding skills.

The migratory period is of special interest to biologists and resource managers interested in sandhill cranes. Much of the consumptive (hunting) and nonconsumptive use (bird-watching and photography) of sandhill cranes occurs during periods of migration. Concentrations of migrating cranes present unique problems and opportunities with regard to census, harvest regulations, crop depredation problems, and habitat preservation and management. Our accumulated knowledge and understanding of the migration ecology of sandhill cranes can be used as a standard with which to compare and contrast information on whooping cranes (*G. americana*) and other species of Gruidae worldwide, whose migrations are not as well understood. Finally, an increased understanding of the specifics of sandhill crane migration contributes to our overall understanding of avian migration in general.

The objectives of this paper are to review and synthesize the presently available information on several aspects of the migration ecology of sandhill cranes and to relate this knowledge to sandhill cranes from Manitoba (Melvin and Temple 1980, Melvin et al. in prep.) and Wisconsin (Melvin 1978).

Summaries of the routes and chronology of sandhill crane migration in North America have been presented by Walkinshaw (1973) and Lewis (1977). Buller (1967) gives more detailed information on fall migration through the Central Flyway, as does Lewis (1974) for crane migration in the southern half of that flyway. Specific data on sandhill crane migration through North Dakota is contained in Madsen (1967), Johnson and Stewart (1972, 1973), Johnson (1976), and Melvin and Temple (in prep.). A steadily increasing body of literature on the use of the Platte River in Nebraska by migrating cranes includes Frith (1974, 1976), Krapu (1979), Lewis (1979a, 1979b), Reinecke and Krapu (1979), Fritzell et al. (1979), and Ferguson et al. (1979).

Early information on the migration of cranes east of the Mississippi was presented by Walkinshaw (1960). More recent information on migration routes through Tennessee and Georgia is contained in Devore (1972) and Patterson (1978). Information on the use of the Jasper-Pulaski Fish and Wildlife Area in northwestern Indiana is contained in Shroufe (1976), Goold (1977), Crete and Toepfer (1978), Melvin (1978), and Lovvorn (1980). Information on the migration of sandhill cranes from Florida is found in papers by Williams and Phillips (1972) and Nesbitt and Williams (1979). Data on the migration of cranes from Wisconsin are found in Gluesing (1974), Howard (1977), Melvin (1977), and Bennett (1978). Drewien and Bizeau (1974) have described the migration of sandhill cranes in the Rocky Mountain states, as have Littlefield and Thompson (1979) for cranes that migrate from Oregon to winter in the Central Valley of California. Boise (1979) presents information on the migration of cranes that breed on the Yukon-Kuskokwim Delta of Alaska.

Recent radio-tracking studies have contributed greatly to our understanding of sandhill crane migration. Crete and Toepfer (1978) radio-tracked sandhill cranes during fall migration from east-central Minnesota and northwestern Wisconsin to Florida and on their reverse migration in spring. Anderson et al. (1980) also tracked Wisconsin cranes during migration to and from Florida. Melvin and Temple (1980) tracked cranes during 2 fall and 1 spring migrations between breeding grounds in the Interlake region of Manitoba and wintering areas along the Gulf Coast of Texas. Drewien and Bizeau (1981) have radio-tracked cross-fostered whooping cranes and their sandhill crane parents during fall migrations between Idaho and New Mexico. The findings of these 4 studies, when taken together and then related to earlier research, have greatly expanded our overall knowledge of sandhill crane migration.

MIGRATION MODEL

Our generalized model of sandhill crane migration describes the movements between and utilization of 3 categories of migration habitat: staging areas, traditional stopover areas, and nontraditional stopover areas (Fig. 1). Cranes begin the fall migration by gathering in increasingly larger flocks at 1 or more staging areas, in relatively close proximity to the breeding grounds. After spending a variable amount of time at these staging areas, they migrate to a traditional stopover area via a series of daily flights. After a stay of variable length at this traditional stopover they continue on to the wintering grounds via another series of daily flights. Nontraditional stopover sites are selected opportunistically for nighttime roosting after each day's flight. The spring migration from the wintering grounds follows essentially the same route as in the fall, with the cranes stopping enroute at a traditional stopover area which may be the same or different from the 1 used in the spring. Between their departure from the traditional spring stopover and arrival on the breeding territories the birds may linger for a brief period at sites in the vicinity of those sites used for fall staging.

The use of the term "staging area" varies slightly within the ornithological literature. Discussing shorebird migrations, Pitelka (1978) defines a staging area as any site where migrating shorebirds prepare themselves physiologically for their next migrational flight. For waterfowl migration, however, Bellrose (1972:14, 1980) uses staging area to refer to sites adjacent to breeding areas where ducks or geese gather at the beginning of fall migration. Bellrose's usage is more nearly analogous to our definition of staging areas for sandhill cranes. Our use of the term "stopover area," distinct from staging area, follows the usage implied by Fredrickson and Drobney (1979), i.e., a stopping place along the migration route that is not in proximity to the breeding grounds.

Staging Areas

Staging areas are sites where sandhill cranes gather during the 1st segment of their fall migration. These sites occur relatively close to the individual breeding territories, usually no more than a day's flight away, and within the 1st 20% of the migration route. As such they can be considered the 1st destinations or "targets" of sandhill cranes during the initial stages of their fall migrations. These areas are often traditional, because the cranes return to them every year (Drewien and Bizeau 1974, Bennett 1978). Annual variations in use may occur, however, due to variations in weather patterns, patterns of food availability, water levels at roost sites, and human disturbance.

Most of the movements to staging areas occur in August or September, after the young of the year have fledged. Gradually the family units (2 adults with 1 or 2 chicks) move off the nesting and chick-rearing territories and begin feeding and roosting with increasingly larger flocks containing other family groups and nonbreeding birds. It is quite likely that groups of nonbreeders that have been in the vicinity all or part of the summer often comprise the nucleus of these initial staging flocks (Bennett 1978, Melvin 1978).

Eventually these local flocks may move on to join larger flocks at secondary staging areas, often traditional sites used every fall, where food resources and roost habitat are more available or of higher quality. Movements to and between staging areas can occur in any direction and are not necessarily along a direct line toward the wintering grounds. Lengths of stay at staging areas are variable and can range from a few days to several weeks.

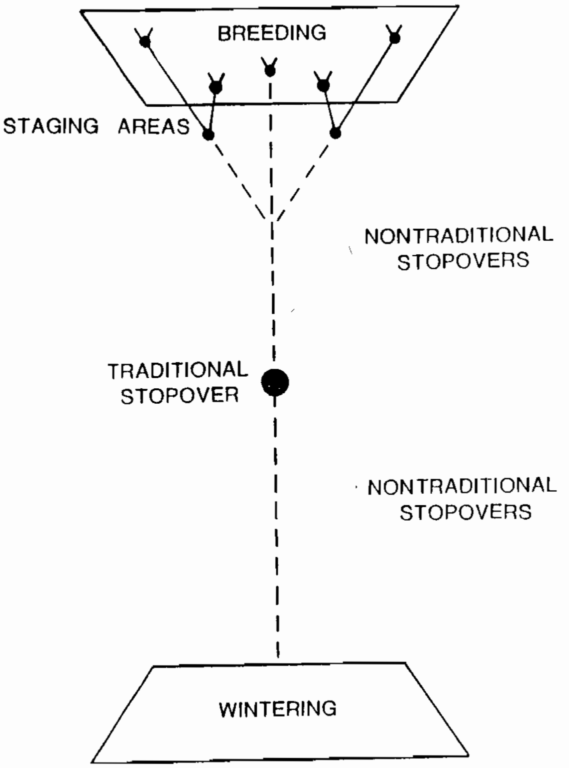

Fig. 1. A generalized model of sandhill crane migration in spring and fall. Solid lines indicate flights that are usually made in a single day; dashed lines indicate flights that require 1 or more overnight stops at nontraditional stopovers.

Sandhill cranes benefit in at least 2 ways by gathering at staging areas during the initial stages of their fall migrations. One of these is physiological-nutritional in nature. Staging areas are often located in agricultural areas where cranes can find abundant food supplies in both harvested and occasionally unharvested fields of corn, wheat, oats, or barley. Pastures, hayfields, and natural grasslands also provide opportunities for feeding and loafing. Often the initial staging areas at which cranes gather are located in the agricultural areas that are closest to the nesting territories. Waste grain represents a high-quality food source for juvenile cranes that are still developing, and for adults and juveniles alike that are beginning to accumulate energy reserves to carry them through the remainder of the migration.

The 2nd benefit of staging areas is social in nature. As the cranes congregate in increasingly larger flocks the aggressive territorial behavior that has kept them dispersed during the breeding season diminishes, and they begin to exhibit a gregariousness which will continue through fall migration, during winter, and through most of spring migration. By staging at the beginning of fall migration, sandhill cranes initiate a mechanism by which migration routes and traditions of older, experienced birds can be passed on to less experienced individuals, especially young of the year on their 1st migration (Hochbaum 1955). Flocking may also allow cranes to more efficiently exploit localized and unevenly distributed resources, such as roosting and feeding sites, along the migration route (Ward and Zahavi 1973, Alexander 1974). Similar flocking behavior is observed in many other avian species before and during migration (Berthold 1975).

Sandhill cranes from Wisconsin, eastern Minnesota, and possibly the Upper Peninsula of Michigan gather in fall at numerous staging areas in Wisconsin before moving south to the traditional stopover at Jasper-Pulaski Fish and Wildlife Area in Indiana. Some of the larger Wisconsin staging areas include: White River Marsh, Widow Green Creek, Colmstock Marsh, and Endeavor Marsh in southeastern Wisconsin (Bennett 1978), the Sandhill Wildlife Area and Necedah National Wildlife Refuge in central Wisconsin (Melvin 1978), and Crex Meadows Wildlife Area in northwestern Wisconsin (Crete and Toepfer 1978). In southern Manitoba cranes gather at staging areas at Big Grass Marsh, Lundar, and Gypsumville before moving south to traditional stopover areas in North Dakota (Melvin and Temple 1980). Sandhill cranes in the Rocky Mountains stage in Idaho at Grays Lake National Wildlife Refuge, Teton Basin, and several other locations, before migrating to the traditional stopover in the San Luis Valley of southern Colorado (Drewien and Bizeau 1974).

Spring staging in the vicinity of the wintering grounds apparently does not occur. The cranes have remained in flocks of varying size all winter, and simply migrate directly from these winter locations toward a traditional spring stopover (Fig. 1). Cranes may return briefly to the vicinity of fall staging areas as they near the completion of spring migration, particularly if weather conditions prohibit an immediate return to breeding territories. Numbers of birds using these sites in spring are more variable and generally smaller than in the fall, and lengths of stay are briefer (Munro 1950, Johnson and Stewart 1972, Melvin 1978).

Traditional Stopover Areas

In contrast to staging areas, traditional stopover areas are located more medially along the migration route (usually between 25 and 75% of the distance between breeding and wintering grounds) and are sites where sandhill cranes stop for extended periods, usually several weeks, during spring and fall migration. They are considered traditional because they are apparently actively sought out and utilized by individual birds year after year, rather than being selected opportunistically and on an irregular basis. Sandhill cranes gather in greater numbers at a traditional stopover area than at any other point along the migration route, reaching peaks numbering in the 1,000's or 10,000's. At present we believe that individual birds stop at only 1 traditional stopover area along each seasonal migration route. Future research may reveal exceptions to this among cranes from breeding areas in Alaska, Siberia, or northern Canada. For example, it is not known if cranes that utilize traditional fall stopover areas in Saskatchewan (Last Mountain Lake and Quill Lake) later move on to the traditional stopover areas in North Dakota.

Traditional stopovers provide abundant food supplies and suitable roosting habitat for migrating cranes. Examples of traditional stopover areas used by different populations of sandhill cranes in spring or fall include: The Platte River in Nebraska (spring), portions of central North Dakota (fall), the Jasper-Pulaski Fish and Wildlife Area in northwestern Indiana (spring and fall), and the San Luis Valley-Monte Vista National Wildlife Refuge in Colorado (spring and fall). These concentrations apparently result in considerable intermixing of cranes from numerous breeding subpopulations, as well as offering unique opportunities for censusing and nonconsumptive viewing.

The potential importance of traditional stopover areas such as the Platte River in allowing cranes to replenish and accumulate energy reserves needed for migration and, in spring, reproduction has been noted by Reinecke and Krapu (1979) and Lewis (1979a). More recently, Iverson (1981) working with midcontinent sandhill cranes, has shown that lipid levels reach their highest annual peak toward the end of the birds' spring stopover along the North Platte River. These findings are supported by earlier work by Lewis (1979a) who found thick fat deposits on cranes collected along the Platte compared to cranes largely without fat deposits collected on the wintering grounds in Texas.

We suspect that during spring migration the bulk of lipid deposition in most populations occurs during the time spent at the traditional stopovers. The relative importance of lipid deposition at fall staging areas versus traditional stopovers has not yet been clearly defined, but probably varies between different populations using different migration routes and is dependent in part on the length of time spent at each location.

Limited data indicate that a majority of sandhill cranes remain at least a month at traditional stopover areas. Lengths of stay may be shorter for certain individuals or subpopulations, particularly those that arrive relatively late in the migration period. Lengths of stay appear to be shorter in spring than in fall for some populations. We assume the amount of time that individual cranes spend at traditional stopovers is governed by the combined influences of weather patterns, the physiological condition and dietary needs of the birds, and conditions at the stopover (e.g., availability and quality of food and roost sites, presence and behavior of other cranes, and frequency of disturbance).

During the fall of 1977, color-marked sandhill cranes from Wisconsin remained at Jasper-Pulaski Fish and Wildlife Area in Indiana for periods of *at least* 19 to 50 days (Melvin 1978). Among 24 color-marked individuals, 23 (96%) remained for at least 20 days, 79% stayed for at least 30 days, and 50% stayed for at least 41 days. Most of these birds arrived in early or mid-October. Radio-tagged cranes from Wisconsin and Minnesota that arrived later, in November, stayed for shorter periods of 6 to 23 days (Crete and Toepfer 1978, Melvin 1978). Radio-tagged cranes in spring 1978 remained at Jasper-Pulaski for periods of 1 to 17 days (average 12 days)(Crete and Toepfer 1978). Melvin and Temple (in prep.), working with radio-tagged sandhill cranes from Manitoba, recorded lengths of stay of 7 weeks or more at traditional fall stopover areas in North Dakota. These Manitoba cranes spent shorter periods of 14 to 28 days at the traditional spring stopover along the Platte River. Drewien and Bizeau (1974) reported that many of the cranes that use the traditional stopover area in the San Luis Valley, Colorado, remain for a month or more in spring and possibly also in fall.

Even fewer data are available on turnover rates at traditional stopover areas, primarily due to the difficulties involved in marking and monitoring a representative sample of any population from arrival to departure. Limited data from censuses and observations of color-marked and radio-tagged cranes at the Jasper-Pulaski stopover (Crete and Toepfer 1978, Melvin 1978) and in North Dakota (Melvin and Temple in prep.) suggest that birds continue arriving until a peak population is reached, and that relatively few departures occur before that peak is reached. Similarly, though new arrivals can be expected after a peak has been reached and departures have occurred or are under way, these late arrivals are probably a small percentage of the total population using the stopover area. If this assumption is correct, censuses of peak crane numbers at traditional stopovers will, if timed properly, count a large percentage of the cranes that pass along that migration route, but will probably always miss some birds that have not yet arrived or have already departed. Lewis (1979b) has noted that censuses of cranes on the Platte River must take into account birds that are still to the south or already north of the river.

It is interesting that traditional stopover areas for a number of subpopulations of sandhill cranes are not located at convenient "half-way points" along the migration pathway (i.e., equidistant between breeding and wintering grounds). Cranes that winter in west Texas and nest in Alberta, Alaska, or Siberia have from 70 to 85% of their spring migration still ahead of them after leaving their spring stopover on the Platte River. Cranes that travel 419 km (260 miles) in fall from breeding grounds in Manitoba to stopover areas in North Dakota must still fly over 2,200 km (1,366 miles) to reach wintering grounds along the Gulf Coast of Texas. Conversely, cranes on their spring migration from Florida to central Wisconsin have already completed over 66% of the journey by the time they reach the traditional stopover at Jasper-Pulaski. We suspect, however, that these disparities in distances to and from traditional stopovers are the result of the strong influences of tradition rather than the evolution of some unique migration strategy.

Sharpe (1978) has hypothesized that the use of the Platte River as a traditional stopover originated during the advance of Wisconsin glaciation, when breeding habitat existed immediately to the north of the river. He speculates that the Platte served as a temporary refuge to early migrants when winter conditions persisted on the breeding areas at the face of the glacier, and that this tradition has persisted to present times.

Although it is possible that events during the Pleistocene played a major role in shaping the present migration patterns of sandhill cranes, it is also true that more recent influences have modified these patterns. Losses of wetlands along migration routes have probably acted to concentrate cranes at certain staging and stopover areas. Certainly the distances between breeding and wintering grounds have increased along some migration routes as breeding populations and nesting areas have receded northward and disappeared from Ohio, Indiana, Illinois, Iowa, and North Dakota. It may be that some present-day traditional stopover areas such as Jasper-Pulaski or portions of North Dakota were once fall staging areas located within or in close proximity to sandhill crane breeding habitat. Walkinshaw (1973) has documented the probable loss of an entire migration pathway that originally connected breeding populations in eastern Ontario with wintering grounds along the mid-Atlantic coast.

Nontraditional Stopovers

Nontraditional stopovers are overnight roost sites selected opportunistically by sandhill cranes at the end of daily migratory flights between breeding and wintering grounds and traditional stopover areas. They are termed nontraditional because the cranes do not actively seek them out or return every year, but instead select them opportunistically as they near the end of a day's flight. Usually the cranes remain only overnight and move on the next day, unless prevented from doing so by inclement weather.

Long-distance radio-tracking studies have begun to document the wide variability in habitat at nontraditional stopovers (Anderson et al. 1980, Melvin and Temple 1980, Drewien and Bizeau 1981). A wide variety of sites may be selected for roosting, including: shallow rivers, natural ponds and lakes, man-made reservoirs and stockponds, and Types 1, 2, 3, and 4 wetlands (Shaw and Fredine 1956). Roosting may even occur on dry land. Uplands surrounding wetland roosts can include agricultural fields, pastures, natural grasslands, and forests. Data are lacking on the characteristics of nontraditional stopovers in the taiga and tundra regions of Canada and Alaska. The basic criteria for a nontraditional stopover, however, seem to be simply a site with shallow water and gently sloping shoreline that is free from disturbance. The fact that cranes often select isolated wetlands and remain only overnight helps explain why cranes are seldom seen on the ground along many portions of their migration route. Other characteristics of the wetland site, including size, visibility from the air, density of emergent vegetation, proximity to woody vegetation, and presence of other cranes, will of course influence the probability that a particular site will be selected for overnight roosting.

Although we refer to these stopovers as nontraditional, this term may not be entirely accurate. Although these sites are not sought out traditionally during each migration, when encountered they must become part of each crane's memory and thus part of its entire perception of its traditional migration route (Hochbaum 1955:52). As such, these sites can be recognized and, perhaps, revisited in later years. This might help to explain a phenomenon observed by Melvin et al. (in prep.) while radio-tracking flocks of cranes between Manitoba and Texas. On several days the flocks veered to the east or west from a previous, relatively straight flight path, during the last hour of a day's flight. These deviations ranged from gradual to abrupt, but usually began before the eventual roost site could have been visible to the birds. On only 1 occasion did wind direction and velocity appear to affect the direction of the deviation. It may be that, when a "decision" had been made within the flock to seek out an overnight roost, 1 or more of the experienced birds acted to guide the others toward the vicinity of a roost site on a lake, river, or marsh recalled from some previous migration.

CHARACTERISTICS OF MIGRATORY FLIGHTS

Until recently it was thought that the bulk of migratory movements by sandhill cranes were undertaken in single, nonstop flights. Cranes were seldom seen on the ground along known migration pathways, except at a few traditional staging and stopover areas; consequently, this suggested that birds flew continuously, day and night, to their destination (Walkinshaw 1960, 1973; Drewien and Bizeau 1974). Although nonstop day and night flights are made by ducks and geese (Bellrose 1980), we now know that this is generally not true of sandhill cranes.

Recent radio-tracking studies have demonstrated that most sandhill crane migration proceeds in a series of daytime flights of variable distance (Crete and Toepfer 1978, Anderson et al. 1980, Melvin and Temple 1980, Drewien and Bizeau 1981). Daily flights begin in the morning, over a period from 1.5 to 5.5 hours after sunrise. The mean departure time of 16 flights of sandhill cranes migrating between Manitoba and Texas was 0943 CST (range from 0819 to 1020, standard deviation of 25.6 minutes)(Melvin et al. in prep.). Nesbitt (1975) noted that 91% of spring departures from Florida occurred between 0945 and 1115 EST, with a mean time of 1016. An unusually early departure in November 1978 was reported by Anderson et al. (1980), when cranes began a migration from northwestern Wisconsin within a half-hour after sunrise.

Sandhill cranes remain airborne each day for periods that vary from 1 to over 10 hours. Migratory flights usually end in late afternoon or early evening (2 hours before to 0.25 hour after sunset) when the cranes land to roost for the night (Anderson et al. 1980, Melvin and Temple 1980, Drewien and Bizeau 1981). Migratory flights may end earlier in the day if the cranes encounter inclement weather or reach a predetermined destination, such as the breeding or wintering grounds or a traditional stopover.

We do not know why cranes wait until mid or late morning to begin migration instead of departing at sunrise. Certainly this behavior does not make efficient use of available daylight, and may increase the number of overnight stops necessary over the course of a long migration. It may be that inefficient use of daylight is offset by the advantages of waiting several hours until the air warms and energy-saving thermals begin to form. Brief early-morning feeding periods may be important to the birds, although we question whether significant contributions to the maintenance of fat reserves are made by such short feeding forays.

Melvin and Temple (1980) recorded average daily ground speeds of 20 to 83 km per hour (12 to 51 mph) for radio-tagged sandhill cranes migrating through the Central Flyway. Average ground speeds reported by other workers in North America fall within these limits (Crete and Toepfer 1978, Anderson et al. 1980, Drewien and Bizeau 1981). Meinertzhagen (1955) estimated ground speeds of migrating common cranes (*G. grus*) at 35 to 58 km per hour (22 to 36 mph) under conditions of little or no wind speed and direction.

Sandhill cranes exhibit a wide variability in the distances they fly each day of migration. A summary of the data from 38 instances in which sandhill cranes were tracked for a complete day's flight (Crete and Toepfer 1978, Anderson et al. 1980, Melvin and Temple 1980, Drewien and Bizeau 1981, pers. comm.) yields a mean flight distance per day of 267 km (166 miles), with a range of 48 to over 740 km (30 to 460 miles) and a standard deviation of 153 km (95 miles). The distance flown each day is dependent upon average ground speed maintained during the flight and the number of hours the cranes choose to remain airborne. Cranes will migrate longer distances each day if they are able to fly with tailwinds rather than against headwinds. Cranes migrating between Manitoba and Texas flew from 520 to over 740 km per day (323-460 miles) when aided by tailwinds of 24 to 48 km per hour (15 to 30 mph), compared to only 48 to 258 km per day (30 to 160 miles) when hindered by headwinds of 8 to 96 km per hour (5 to 60 mph).

Similarly, cranes flew relatively longer distances on days when they took off in mid-morning and flew until nearly sunset than on days when they took off later in the morning and landed an hour or more before sunset. Obviously, late take-offs and early landings fail to take full advantage of the number of hours of daylight available for flight.

Proposals to acquire and preserve migration habitat for sandhill cranes must consider the fact that sandhill cranes are highly variable in the distances they migrate each day and are opportunistic in their selection of roost habitat at nontraditonal stopovers. Anderson et al. (1980) stated that roost habitat should be secured at intervals of 250-350 km (155-217 miles) along the migration route between Wisconsin and Florida for cranes forced to land by inclement weather. Similarly, Crete and Toepfer (1978) noted that roost habitat spaced 272-384 km (169-238 miles) or 1 "crane-day" flight apart could provide additional stopovers during migration. We believe that such specific recommendations are unrealistic and will not produce the expected results, i.e., a stepping-stone migration between a series of evenly spaced stopovers.

The great variability in distances flown each day demonstrates that the concept of an average daily flight distance is of little practical value. Sandhill cranes will usually remain airborne until approaching darkness or bad weather forces them to land, and our observations indicate that they will not land earlier in the day simply because they are passing near what appears to us to be suitable or even "optimum" roost habitat. Furthermore, cranes that encounter inclement weather will have little time or opportunity to seek out and make their way to suitable roost sites. Thus, we suggest that evenly-spaced roost sites will receive no greater crane use than will an equal amount of randomly spaced roost habitat located along the same route. We recommend that priority be given to preserving and improving roosting and feeding habitat at staging and traditional stopover areas, because these areas appear to be of greatest physiological and social value to migrating cranes. With regard to nontraditional stopovers, we should recognize that it is not sufficient to preserve only a handful of evenly spaced islands of habitat, but should seek to maintain as high a density of wetland habitat as possible all along each migration route.

Flight Behavior

Migrating sandhill cranes utilize 3 basic types of flight: flapping, gliding, and spiralling (Melvin and Temple 1980). Flapping is powered flight with continuous wingbeats, requiring more energy than gliding or spiralling. Direction of movement is straight ahead during flapping flight, with the cranes flying horizontally at a relatively constant level above the ground. During gliding flight the cranes hold their wings outstretched and motionless, and glide forward seemingly effortlessly. Gliding flight is usually accompanied by a gradual decrease in altitude. Various gradations of flapping and gliding flight, termed "partially powered" flight by Pennycuick et al. (1979), are also seen, in which bursts of a few wingbeats are interspersed with gliding.

Spiralling flight by sandhill cranes involves soaring in thermals, similar to that described for a number of avian species (Pennycuick 1972). While holding their wings outstretched and motionless, or occasionally flapping, the cranes circle continuously and spiral upwards on rising updrafts. As the cranes spiral up in tight flocks, all of the birds soar in the same direction. This is in contrast to the pattern of soaring migration of white storks (*Ciconia ciconia*), described by Pennycuick et al. (1979), in which the birds circle indiscriminantly in either direction. In spiralling flight by sandhill cranes the main direction of movement is circular. While spiraling upward the cranes make little if any forward progress on their own, and their ground speed and overall direction of flight are determined largely by existing wind conditions.

After reaching a certain altitude via spiralling flight, the cranes will proceed forward again using combinations of gliding and flapping flight. Pennycuick et al. (1979) have described in detail the use of spiralling, flapping, and gliding flight in migrating common cranes and have analyzed the energetics and aerodynamics of these types of flight. Presumably these findings are applicable to sandhill cranes, which exhibit similar flight behavior during migration. Spiralling flight allows the birds to rise 1,000 m or more with minimal energy expenditure, because most of the climb is produced by rising thermals rather than by powered flight. From the top of the spiral the cranes can glide forward for great distances with little expenditure of energy. The forward progress of the birds is slower than if they proceeded by continuous flapping flight, but this disadvantage of extending the time spent in migration is balanced by a decrease in the total amount of energy needed to complete the trip.

Sandhill crane migration proceeds via a combination of all 3 types of flight. Steady flapping flight is used more frequently during periods when thermals are absent, infrequent, or widely scattered, as in early to mid morning, early evening, and on cold or cloudy days. Powered flapping flight is usually used when cranes are flying at low altitudes above the ground, and is almost always used in flights between roosts and feeding areas. We have also observed steady, low-altitude flapping flight when cranes proceeded against strong headwinds.

Spiralling flight is more common during late morning and through the afternoon and on sunny days when thermals are most prevalent. Birds travel between thermals via combinations of gliding and flapping flight. Cranes thermaling with tailwinds continue to move in the general direction of migration, albeit at a slower rate than when in flapping or gliding flight. Cranes spiralling into headwinds may actually lose ground during the spiral as they are gradually blown backward. We have observed southward migrating sandhill cranes in Texas flying into southeast to southwest headwinds of 11 to 24 km per hour (7 to 15 mph), yet still spiralling. Skies were sunny and warm, probably resulting in excellent conditions for thermals. Although the cranes made slow progress on these days, alternate spiralling and gliding flight allowed them to migrate for hours against unfavorable winds with, presumably, a minimum energy expenditure.

When flapping or gliding, flocks of sandhill cranes organize into linear formations, either V- or J-shaped or single lines. When spiralling flight begins the flock breaks into a less-organized cluster, with all birds circling gradually upward and in the same direction. Why sandhill cranes use formation flight is uncertain. Lissaman and Schollenberger (1970) proposed that Canada geese (*Branta canadensis*) fly in V-formation to capitalize on upward-rising components of the wingtip vertex currents generated by the wings of neighboring birds flying to the front and side. Gould and Heppner (1974) and Williams et al. (1976) have suggested, however, that V-formation flight by

Canada geese is probably not the result of a simple aerodynamic relationship, but may have behavioral components as well. Flight formations may function to maintain flock unity and spacing between individuals, and perhaps also aid in navigation, by averaging the direction preferences of individual birds (Hamilton 1967, Heppner 1974). Hamilton (1967) proposed that the V-formation is advantageous for within-flock communication because it allows a high degree of visual communication with neighboring birds, at the same time leaving a clear field of view to the front.

Height of Migration

Although the heights at which sandhill cranes migrate are variable, available evidence indicates that the bulk of migration occurs within 1,600 m (5,250 ft) of the ground. Cranes migrating through the Central Flyway flew from 60 to 1,600 m (197 to 5,250 ft) above the ground, and nearly 75% of the flights were between 150 and 760 m (492 and 2,493 ft) above ground (Melvin and Temple 1980). Heights of migrating cranes reported by Crete and Toepfer (1978) fall within these limits. Radar observations by Keil (1970) indicated that the altitude of common cranes migrating over Germany varied between 46 and 1,830 m (150 and 6,000 ft), although observations above 915 m (3,000 ft) were rare. The highest altitude of migrating sandhill cranes observed by Melvin et al. (in prep.) was 2,073 m (6,800 ft) above sea level. Sandhill cranes migrating through the Rocky Mountains, however, have been recorded over 3,660 m (12,005 ft) above sea level (Drewien and Bizeau 1981).

The height of migrating sandhill cranes may fluctuate continually and by hundreds of meters during the course of a day's flight (Melvin and Temple 1980, Drewien and Bizeau 1981). These fluctuations appear largely due to: (1) changes in elevation of the ground below, and (2) the effects of rising thermals utilized during flight.

Nighttime Migration

Reliable information on the extent of nighttime migration by cranes is scarce. Walkinshaw (1949) felt that crane migration occurred by night and day, and Walkinshaw (1973) and Patterson (1978) suspected that sandhill cranes flew continuously through the 1st night of spring migration. Alerstam and Bauer (1973), however, concluded from radar studies that common cranes in Europe migrated only by day. Madsen (1967) believed that sandhill cranes migrated from his study area in North Dakota during the night of 2 November 1965, when a cold front with strong northwest winds moved in. He based this belief on the fact that cranes could not be located on the ground the following morning. Littlefield and Thompson (1979) reported that sandhill cranes from Oregon may fly through the night in order to complete their relatively short fall migration to the Central Valley of California.

More recent data, particularly that collected from long-distance radio-tracking studies, indicate that sandhill cranes are primarily diurnal migrants, and only occasionally continue a flight after dark. A flock containing radio-tagged cranes tracked by Crete and Toepfer (1978) across Georgia into Florida did not land to roost until 3 hours after sunset (Anderson et al. 1980). Cranes tracked on a flight from Kansas into Texas continued migration for at least 1.5 hours and 129 km (80 miles) after dark (Melvin and Temple 1980). Anderson et al. (1980) suspected that radio-tagged cranes migrating across Georgia and into southern Tennessee continued for several hours after dark. Lewis (1974) reported the arrival of several hundred cranes at Quivera National Wildlife Refuge, Kansas, during the night of 27-28 October 1969.

Based on the available evidence, we conclude that sandhill cranes are primarily diurnal migrants. This is supported by numerous observations of migratory flights by radio-tagged cranes that began after sunrise and were terminated before sunset. Sandhill cranes will, however, occasionally remain airborne into the night to complete flights begun the previous day. Our limited observations further suggest that these nocturnal flights occur under conditions of favorable or calm winds after a daytime flight aided by tailwinds, and that they may be more likely to occur as cranes approach a predetermined destination.

FACTORS CONTROLLING MIGRATION

There are 2 broad categories of factors that cause migration in birds, including, presumably, sandhill cranes. These are ultimate factors and proximate factors (VanTyne and Berger 1976). Ultimate factors are those which have exerted a positive selective evolutionary influence on those birds that developed migratory behavior. In other words, ultimate factors are those which have made migratory behavior advantageous to a species. For sandhill cranes these probably include abundant wetlands for nesting and reduced competition for food on the breeding grounds during summer, and a more favorable energy balance due to accessible food supplies and warmer temperatures on the wintering grounds.

Proximate factors are those which stimulate a migratory state or condition in the individual and which lead to actual migration. Proximate factors can be further grouped as internal or external. Certain internal conditions must predispose sandhill cranes to migrate, and then external factors act as stimuli to initiate migratory behavior. The migratory state in sandhill cranes is probably regulated internally by neuroendocrinological mechanisms governed largely by changes in photoperiod, as it is in most other birds (Berthold 1975, Gwinner 1975).

External proximate factors that act to fine tune the timing of migration in sandhill cranes are weather conditions, particularly wind and cloud cover, and behavioral stimuli from other cranes. Each of these will be considered separately.

Effects of Weather

Weather influences crane migration in 2 important ways. First, it acts as a stimulus that initiates migration in birds that are physiologically prepared for it, and it can also have an inhibitory influence by temporarily halting migration. Secondly, weather has a profound effect on migrating cranes in flight, by either helping them, hindering them, or forcing them to the ground.

Weather has its greatest stimulatory effect on the initiation of fall migration from the breeding grounds, staging areas, and traditional stopovers, and in spring from wintering areas and traditional stopovers. Fall migration from these sites usually begins under conditions of north or northwest winds and clear to partly cloudy skies (Melvin et al. in prep). The heaviest fall migrations are initiated under conditions of clear skies, strong northwest winds, and cool temperatures that are usually associated with high-pressure systems. These are similar to fall migration conditions reported for many other species (Richardson 1978).

Heaviest departures in spring occur with clear to partly cloudy skies and south or southeast winds. Winds with a northerly vector and skies that are at least partly sunny appear to be the most important of the weather stimuli for fall migration (Melvin et al. in prep). Nesbitt (1975) has documented the importance of southeasterly winds and at least partly clear skies in stimulating crane migration from Florida wintering areas. Although ambient temperature may play a role in regulating migration, we suspect it is less a cause of migration than a product of other controlling factors, e.g., clear skies and cold north winds in fall, and warm southerly winds in spring.

Departures from breeding and wintering grounds, staging areas, and traditional stopovers are inhibited by rain, snow, fog, unfavorable winds, and low unbroken cloud cover, and migration from these sites is almost never initiated under these conditions. Unfavorable winds are those without a north component in fall, or a south component in spring. An exception to this was reported by Anderson et al. (1980) when a flock of sandhills departed Crex Meadows Wildlife Area in northwestern Wisconsin during a snowstorm on the morning of 19 November 1978. Cranes that delay their departure until very late in the fall may eventually elect to begin migration under less than ideal conditions.

The selective advantages of beginning a migration under conditions of clear skies and favorable winds are obvious. Flying with a tailwind requires less energy to cover a given distance than under other conditions and results in a minimum energy cost of transport (Tucker 1974). By waiting for these conditions to occur the cranes increase their chances of completing all or a major part of at least the 1st day's flight with energy-conserving tailwinds and without encountering inclement weather.

Sandhill cranes are less particular about weather conditions after they have begun a migration, and are more likely to depart from a nontraditional stopover or continue a day's flight under suboptimum conditions. Unfavorable winds and low overcast may prevent cranes from taking off, but not always. We have observed cranes remain grounded at nontraditional stopovers under conditions of 100% overcast and threatening rain, and by 8 to 16 km per hour (5 to 10 mph) headwinds. In contrast, we have observed cranes begin and continue flights into headwinds as strong as 56 to 96 km per hour (35 to 60 mph), and have seen them take off soon after cessation of a rain shower and under continuing low, unbroken clouds (Melvin and Temple 1980). Our experience tracking migrating sandhill cranes between Manitoba and Texas has been that precipitation and fog will always keep cranes grounded at nontraditional stopovers. Crete and Toepfer (1978) and Anderson et al. (1980) also reported that while enroute cranes remained grounded by rain, snow, and fog.

Our observations indicate that airborne cranes are usually forced down by precipitation. Flights may continue through brief, scattered showers, however, and cranes forced to land by showers at midday may continue their migration that afternoon if conditions improve (Melvin and Temple 1980). Cranes may continue to fly all day against headwinds or crosswinds, but will often land if headwinds are strong, 32 km per hour (20 mph) or more, and persistent. Cranes tracked by Crete and Toepfer (1978) and Anderson et al. (1980) also occasionally migrated into headwinds, particularly during spring migration from Indiana to Wisconsin and Minnesota. It may be that sandhill cranes are more inclined to fly against headwinds during spring migration, when motivated by a strong urge to complete the migration and reach the breeding grounds.

Behavioral Stimuli

Sandhill cranes exhibit gregarious flocking behavior throughout each migration, and we suspect that behavioral interactions play an important part in the migration process. Certainly when a crane has reached a physiological state of readiness, and the initiation of migration has been stimulated by favorable weather conditions, the final impetus to take off and begin a migratory flight is often provided by the sight of nearby birds adopting a preflight posture and then taking flight (Voss 1975, Tacha 1981), or of other flocks of cranes passing overhead. Probably the strongest stimulus to migrate for young of the year on their 1st migration is the sight of their parents and other nearby birds taking flight.

Vocalizations also seem to play an important part in these behavioral interactions. Cranes in migrating flocks call to each other constantly, as do cranes on the ground as airborne flocks pass overhead or descend to land among them. The migration call is a relatively short and high-pitched call given intermittently by 1 or more members of a migrating flock in flight (Melvin et al. in prep.). It is audible from great distances, and is often heard by observers on the ground before a high flying flock becomes visible. Presumably these migration calls serve as a form of communication within the flocks, and may be analogous to the nocturnal call notes used to maintain contact by migrating flocks of passerines (Hamilton 1962). The sight and sound of a flock of cranes passing overhead and calling appears to be a stimulus for cranes on the ground to begin migrating (Melvin et al. in prep.). Conversely, migrating cranes at the end of a day's flight, that are already predisposed to seek an overnight roost, may be attracted to cranes "unison calling" (Archibald 1976) from the ground.

Vocalizations and behavioral interactions must also function to aid cranes at staging and stopover areas to more efficiently use food resources and roost sites. Groups of cranes follow each other back and forth between feeding and roosting areas along what often become established flight lines. The presence of cranes already on the ground and calling often seems to attract cranes in the air to a particular feeding field or roost site. Madsen (1967) suggested that in North Dakota only the 1st few cranes to arrive at a particular habitat actually selected that habitat, all others merely joining them because of their gregarious nature. Feeding and roosting habitat along the migration route often occurs in a patchy (clumped) distribution, and in unfamiliar areas such patches may be more efficiently located by cranes that make use of these behavioral interactions (Ward and Zahavi 1973).

HUNTING AND MIGRATION

Disturbance from hunters may accelerate the migration chronology of sandhill cranes and affect their distribution at staging and stopover areas. In southeastern Wisconsin the departure of sandhill cranes from fall staging areas coincides closely with the opening of waterfowl hunting season in early October (Bennett 1978). Most of the roost sites at these staging areas are located on privately owned wetlands, and the cranes are intolerant of the heavy and continual hunter disturbance.

Major crane staging areas in central Wisconsin, in contrast, are located on state and federally controlled wetlands where cranes are not disturbed on the roosts by hunters. As a result cranes remain in central Wisconsin longer in the fall, through late October (Melvin 1978). Similarly, cranes formerly left staging areas in southern Michigan by mid-October as a result of disturbances from waterfowl hunters. Since the establishment of the Haehnle and Baker sanctuaries at these sites, and their closure to hunting, the cranes remain into November and sometimes December (Walkinshaw and Hoffman 1974, Hoffman 1977). In 1977 the migration from Minnesota of a radio-tagged crane coincided with the opening of that state's waterfowl season (Crete and Toepfer 1978). At the Jasper-Pulaski Fish and Wildlife Area in Indiana, waterfowl hunting from 0.5 hour before sunrise until noon or sunset every other day in 1979 caused marked avoidance of particular roosts by cranes (Lovvorn 1980).

Sandhill cranes at traditional stopovers in North Dakota may avoid disturbances (and mortality) from crane hunters by moving to nearby areas where hunter pressure is reduced or absent (Melvin and Temple 1980). The chronology of migration from North Dakota is not accelerated by hunter disturbance, however, presumably because: (1) hunting pressure occurs early in the migration period, when cranes may be less predisposed to migrate, and (2) high densities of wetlands and relatively low densities of hunters allow cranes to find secure roosts by moving only short distances.

Certain aspects of crane migration should be considered whenever sandhill crane harvest regulations are to be established or revised for a given location. Which breeding subpopulations are using that area, and what is the chronology of their migration (i.e., dates of arrival and departure and average lengths of stay for a substantial portion of each subpopulation)? Do some subpopulations arrive substantially earlier or later than others? Is the area primarily used for staging, a traditional stopover, or nontraditional stopover? Does this use vary for different subpopulations?

Hunting at fall staging areas will have a greater effect on local birds and probably runs a greater risk of over-harvesting small, discrete subpopulations than will hunting at a traditional stopover, where several subpopulations will be intermixed and hunting pressure is presumably evenly distributed. Hunting pressure at a traditional stopover may not be evenly distributed, however, if certain groups of birds arrive earlier or later or stay substantially longer than others. Such a situation has been demonstrated for sandhill cranes from the Interlake region of Manitoba, that arrive early at traditional stopover areas in North Dakota and are subjected to hunting pressure that is reduced or absent for cranes that arrive later in the fall after part or all of the crane hunting season (Melvin and Temple in prep.).

It should also be realized that opportunities for sandhill crane hunting will be greater at locations used for traditional stopovers than at nontraditional stopovers. This is simply because the former will attract greater numbers of cranes each fall, and they stay for longer periods of time. This explains why, in the Central Flyway, North Dakota annually harvests 4.5 to 6 times as many cranes as South Dakota and Oklahoma combined (Sorenson 1979, 1980, 1981). States that might wish to begin harvesting cranes (e.g., Kansas or Nebraska) or increase their harvest opportunities by liberalizing regulations or initiating habitat management programs to attract more cranes, e.g., South Dakota and Oklahoma, should realize that, at present, most cranes are probably using these states primarily for nontraditional stopovers. This usually means relatively low numbers of cranes on the ground at any given time, brief stays by most birds that do stop, and unpredictable numbers of birds at most locations from year to year. Thus, such states may not be able to substantially increase their harvest opportunities by increasing season lengths and bag limits or by providing more migration habitat, as long as traditional migration patterns continue and result in the majority of migrant cranes overflying these states or stopping only briefly in transit.

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ROOST HABITAT SELECTION BY SANDHILL CRANES IN CENTRAL NORTH DAKOTA

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Abstract: Roost habitat selection of migrating sandhill cranes was studied in central North Dakota during fall 1980. Fourteen variables were measured on 15 roost and 15 nonroost sites. Principal components analysis reduced the variables to 5 factors which explained 78% of the total variability. A discriminant analysis of these 5 factors showed a significant difference ($P < 0.001$) between roost sites and nonroost sites, indicating that cranes are not selecting roost sites at random. Factor 2, which is highly correlated with average water depth, bottom slope, distance to nearest shore, and firmness of the bottom substrate, had the greatest discriminating power. This indicates that the habitat characteristics most important for sandhill crane (*Grus canadensis*) roost site selection are large expanses of shallow water that are not close to shore, and a soft (muddy or silty) bottom substrate.

INTRODUCTION

Sandhill cranes stage in various areas of central North Dakota, primarily Kidder, McLean, and Pierce counties during fall migration (Johnson 1976). Data collected in recent years suggest the importance of these areas for Central Flyway populations of sandhill cranes (USDI 1979, Melvin and Temple 1980, USDI 1980). For example, cranes have remained up to 7 weeks in Kidder County and vicinity (Melvin and Temple 1980) and 4 weeks in McLean County (Martha Carlisle, pers. comm.). Also, peak numbers of cranes in an area in McLean County were approximately 19,500 and 21,350 in 1978 and 1979, respectively (USDI 1979, 1980).

Two important aspects of these fall staging areas are food availability and evening roost sites. Migrating sandhill cranes feed in stubble fields and pastures during the day, and congregate to preen and sleep at roost areas during the night. The cranes seem to be attracted to a certain type of habitat for roost areas. Johnson and Stewart (1972:66) state, "Sandhill Cranes . . . are very selective about their habitat while enroute." Most wetlands utilized as roosting sites in North Dakota seem to have certain common factors which include alkaline lakes in glacial outwash plains with little or no emergent vegetation, flat terrain to allow good visibility of approaching danger, shallow water, and adjacent freshwater fen pockets or man-made dugouts for drinking (Johnson and Stewart 1972, Johnson 1976).

Although these criteria seemed to be important, no definite measurements or analysis had been made in North Dakota to determine whether these characteristics, tradition, or coincidence influence use of roost areas. If habitat characteristics are important, there is need for a finer distinction to determine their relative importance.

The objectives of this study were to determine if roost sites differed from potential roost areas that were not used, and to determine habitat factors characteristic of roost sites used by sandhill cranes during their fall migration through McLean County, North Dakota.

I express my deepest appreciation to the following people for their help throughout the study: my advisor, Dr. James W. Grier, for his suggestions in all phases of the study; Douglas Johnson for his help with study design, data analysis, and manuscript review; Water and Power Resources Service biologists Richard McCabe, Glen Gould, Timothy Patton, and Michael Johnson for their help in many ways and cooperation in the use of their crane roost data; Dr. Gary Clambey, Dr. Dhanwant S. Gill, David Evans, and Dr. Jeffery Gerst for their suggestions with data analysis; Mohammed Syamsum for his suggestions on computer problems; John Fleckenstein for his assistance in the field; Dr. James Brammer for locating funds for field work; and especially to Martha Carlisle, without whose help, suggestions, and extended efforts this study would have not been possible.

STUDY AREA

The 220-km^2 study area in central McLean County, North Dakota, extends from the Lake Nettie National Wildlife Refuge area in the northwest to Blue Lake in the southeast (Fig. 1). It is sit-

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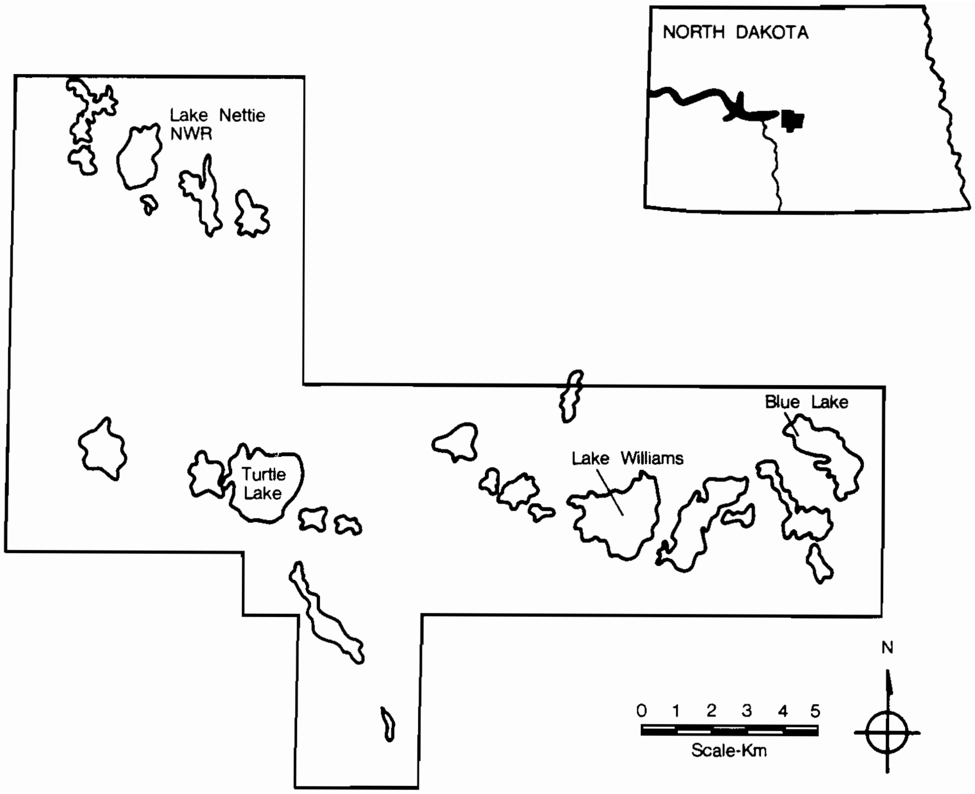

Fig. 1. Study area and location of major lakes in central McLean County, North Dakota.

uated in a glacial outwash plain and has numerous poorly drained, shallow wetlands. Most of the wetlands can be classified as the palustrine system, emergent wetland, or unconsolidated bottom class, permanently to seasonally flooded water regime, with alkaline and saline to mixosaline chemistry (Cowardin et al. 1979). Most of the upland is idle or cultivated cropland and pasture. Native vegetation is primarily adjacent to larger wetlands, especially around the chain-of-lakes area from Lake Williams to Blue Lake.

This vegetation is usually mixed grass prairie, with dominant species being western wheatgrass (*Agropyron smithii*), prairie junegrass (*Koelaria cristata*), needle-and-thread (*Stipa comata*), blue grama (*Bouteloua gracilis*), and needleleaf sedge (*Carex stenophylla*)(Stewart 1975). Emergent wetland vegetation is primarily alkali bulrush (*Scirpus paludosus*), hardstem bulrush (*Scirpus acutus*), phragmites (*Phragmites communis*), and various sedges (*Carex* spp.). The dominant species surrounding alkali lakes are alkaligrass (*Puccinellia nuttalliana*), saltgrass (*Distichlis stricta*), and sea-blite (*Suaeda depressa*)(Stewart 1975). The upland soils are part of the Ruso-Bowdle-Wabek association, which consists mostly of moderately coarse to medium soils (USDA 1979).

This area was selected for 1 primary reason--the Water and Power Resources Services conducted extensive aerial surveys over this area from early September to mid-November, 1980. Six mornings a week they monitored sandhill crane and whooping crane (*Grus americana*) usage at sunrise before most cranes had left the roosts. This information was used to locate all roost sites in the study area.

METHODS

The study was conducted during the fall of 1980, primarily during the peak of fall migration. Fifteen roost sties were randomly selected where cranes had roosted at least once that season, and 15 nonroost sites were randomly selected where cranes had not, but could potentially roost. Criteria for nonroost site selection were wetlands of at least 2 ha that had water less than 30 cm deep at least 5 m from shore and which were devoid of extensive emergent and submergent vegetation The sampling unit for both roost and nonroost sites was a point that was selected randomly at each site.

Several measurements were taken at each sample point. Water depth and crane depth were measured with a device that consisted of a 1-inch wooden dowel marked in centimeters, with a 2-inch-diameter plastic disc on the bottom and weights on the top. The proportion weight:surface area was adjusted to simulate the step of a crane. The device was set into the water until the plastic disc was just on top of the bottom substrate to obtain a water depth reading. Then it was allowed to drop freely into the substrate to obtain a crane-depth reading. Crane depth is a measure of how much a crane will sink into the bottom substrate. A silty or muddy substrate will have a larger crane depth than a sandy or gravelly substrate.

Other measurements at the sample point included distance to and height of the nearest vegetation, distance to and width of the nearest bare shore or exposed sandbar, specific conductance, and compass bearings to any visible buildings or farmsteads. A portable conductivity meter measured conductance in mmhos/cm^3, and distance to all visible points was set and measured in straight lines on 7.5-minute USGS quadrangle maps.

There were also several measurements taken outside the sample point in 4 four cardinal directions. Water depth, crane depth, and height of vegetation encountered were taken at 10-m intervals up to 50 m. Also, distance to, and slope of, the nearest crest were measured, unless the distance was greater than 200 m. Distance was paced, and slope was estimated with a Brunton compass.

Derivation of Variables

Fourteen variables, derived from the measurements taken, are listed in Table 1. Height of crest was derived trigonometrically from hypotenuse length (distance to crest) and degree of the angle adjacent to the hypotenuse (angle of slope). Average height of crest is the mean at each site of the height in the 4 directions; average distance to crest is derived in the same manner. Both are measures of the physiography of the surrounding terrain.

Table 1. Variables derived from habitat measurements at crane roost and nonroost sites in Central North Dakota.

Variable	Unit	15 roost sites		15 nonroost sites	
		Range	Mean ± SE	Range	Mean ± SE
Average height of crest	m	0.0-7.9	2.9 ± 0.6	0.4-9.6	2.3 ± 0.6
Visibility index	m	0.0-106.2	59.0 ± 8.9	0.0-148.5	41.1 ± 12.6
Average water depth	cm	1.0-25.1	10.0 ± 1.5	6.9-61.4	25.8 ± 3.1
Average crane depth	cm	0.3-4.8	2.5 ± 0.3	0.0-3.1	1.1 ± 0.2
Average bottom slope	cm/m	0.0-0.6	0.2 ± 0.1	0.2-1.6	0.7 ± 0.1
Distance to nearest shore	m	8.0-50.0	19.4 ± 3.6	1.0-30.0	5.5 ± 1.8
Distance to nearest road	m	125.0-1900.0	1055.0 ± 132.6	50.0-2200.0	721.7 ± 158.3
Distance to nearest farm	m	400.0-3100.0	1663.3 ± 196.2	500.0-2900.0	1541.7 ± 228.9
Percent open area	%	10.0-100.0	69.3 ± 7.3	25.0-85.0	55.7 ± 3.8
Distance to vegetation	m	0.0-125.0	29.1 ± 9.2	0.0-22.0	6.6 ± 1.6
Width of bare shore	m	0.0-72.5	20.6 ± 5.7	0.0-40.0	6.7 ± 2.8
Specific conductance	mmhos/cm^3	2.0-53.0	16.7 ± 4.3	3.6-35.0	11.7 ± 2.1
Vegetation height	cm	2.0-57.5	23.1 ± 4.5	2.7-80.0	23.1 ± 4.9
Average distance to crest	m	90.0-221.0	177.8 ± 9.7	86.2-200.0	143.3 ± 7.8

Visibility index indicates the amount of visual isolation from human habitation and hazards at the site. Human habitation and hazards include visible points such as farmsteads, occupied or unoccupied buildings, roads, powerlines, and trees. The index is from the formula

$$\mathrm{VISIN} = \Sigma(G - N)\ N$$

where VISIN is visibility index, G is the greatest distance that all points were seen, D is the distance to a visible point, and N is the number of visible points for a site. For example, a site that was completely isolated would receive a VISIN of 0, one that had 6 close visible points would receive a very high number, and 1 that had 3 distant points would receive a number between the first 2.

The average bottom slope is a measure of how rapidly the water depth changes from the sample point. It is derived from the formula

$$\mathrm{BOTSLP} = \overset{1}{\underset{n}{\Sigma}} \frac{(WD_1 - WD_2)}{d}$$

where WD_1 is the water depth of the farthest measurement along a transect, WD_2 is water depth at the sample point, d is distance to the farthest measure along the transect (from 0 to 50 m), and n is the number of transects along each site (from 1 to 4). The absolute value of these measurements was used because a positive change in slope along 1 transect was usually paired with a negative change in slope along the opposing transect.

Percent area open is an estimate of the amount of area surrounding the sample point that is devoid of emergent vegetation. Each of 4 transects composed 25% of the area, with all 4 totaling 100%. Five percentage points would be subtracted from 25% for vegetation encountered at each 10-m sample point along a transect. For example, if vegetation was at 40 and 50 m along 1 transect on a site, the value for that transect would be 15%. If vegetation was not encountered along the remaining transects, the value for that site would be 75% + 15% = 90%.

Water depth and crane depth are the mean of all measurements taken at a site. Vegetation height is the height of the nearest vegetation. The remaining variables require no explanation.

Multivariate Analysis

Data analysis involved the multivariate techniques principal components analysis (PCA) and 2-group discriminant function analysis (DFA). The Factor Analysis and Discriminant Analysis packaged programs in Statistical Analysis Systems (SAS 1979) were used to perform the analysis on an IBM 370-158 computer.

PCA is a method that describes the relationships among variables in a data set. New variables (factors or principal components) are generated that often reduce the dimensionality of the original data set by explaining a large proportion of the entire variability with fewer of these new variables than the original. Thus, the new data structure is a set of reduced factors that are used to explain the relationships among the variables in the original data set. Each new factor is actually a linear combination of the original variables with weights on each variable that are used to interpret the factors. Also, these new factors are uncorrelated (orthogonal), which is often necessary for follow-up tests (Harris 1975).

Two-group DFA is a technique used with a data set that has 2 a priori groups and several predictor variables. The purpose is to reduce this group of predictor variables into 1 linear composite (discriminant function) that maximally discriminates between members of these 2 groups. When this is done, a test can be run to determine if the 2 group centroid differ significantly. Also, this linear composite can be used to classify old observations into 1 of the 2 groups, or predict to which groups any new observation belongs (Green 1978).

RESULTS

Table 1 lists the unit of measure, range, mean, and standard error for roost and nonroost sites of the 14 variables. The results of the PCA on the 14 variables are shown in Table 2. A correlation matrix was used in the analysis because many of the variables had very different units of measure. Five factors had an eigenvalue greater than 1 and were retained. These 5 factors explained 78% of the total variability in the original data set. They were not interpretable, however, because most of the variables only had heavy loadings on Factor 1. To solve this problem, the varimax rotation method was applied to the 5 factors.

Table 2. Eigenvalues and percent variability for 5 retained factors.

	Factor				
	1	2	3	4	5
Eigenvalue	4.49	2.09	1.90	1.44	1.04
Percent of total variability	32	15	14	10	7
Cumulative percent	32	47	61	71	78

Varimax is a rigid rotation that attempts to maximize the variance within each factor. The rotated factors are still orthogonal, and the total amount of variability accounted for remains unchanged, but the eigenvalue for each factor may change. The outcome of the rotation is a set of factors that are more easily interpreted by distributing high loading more evenly among factors (Green 1978).

Table 3 shows the results of the varimax rotation. The eigenvalues changed for each factor, but the factors are now interpretable. Factor 1 describes the surrounding terrain with a high negative loading on average crest height, and a high positive loading on the visibility index. This indicates that sites with high surrounding terrain are more visually isolated than those with lower surrounding terrain. Factor 2 is associated with water basin characteristics. It has high negative loadings on water depth and average bottom slope, and high positive loadings on crane depth and distance to nearest bare shore or sandbar. Factor 3 can be described as a human disturbance factor with high positive loadings on distance to nearest farm and distance to nearest road. Factor 4 has high positive loadings on percent area devoid of emergent vegetation, distance to nearest vegetation, specific conductance, and shore width. The positive loadings suggest a strong positive relationship between salinity and vegetation growth, as would be expected. Factor 5 has a high loading on vegetation height. The variable average distance to crest was not strongly correlated with any of the first 5 factors.

The DFA was run on the 5 rotated factors, Factor 1 through Factor 5, derived from PCA. This analysis resulted in a distance between group centroids (D^2) of 5.87. The D^2 is used to calculate

Table 3. Factor loadings after varimax rotation for 5 retained roost habitat factors.

	Factor				
Variable	1	2	3	4	5
Average height of crest	-0.74	0.38	-0.17	-0.13	-0.21
Visibility index	0.79	0.05	-0.20	-0.14	-0.17
Average water depth	0.21	-0.88	-0.11	-0.09	0.10
Average crane depth	-0.03	0.84	0.00	0.09	0.20
Average bottom slope	0.10	-0.87	-0.14	-0.28	0.10
Distance to nearest shore	0.41	0.65	0.04	0.18	0.17
Distance to nearest road	0.12	0.13	0.84	0.15	0.20
Distance to nearest farm	-0.23	0.06	0.83	0.08	-0.12
Percent open area	0.13	-0.05	0.20	0.83	0.15
Distance to vegetation	0.26	0.37	0.22	0.75	0.08
Width of bare shore	-0.07	0.46	-0.22	0.76	-0.25
Specific conductance	-0.34	0.14	0.09	0.75	-0.01
Vegetation height	-0.00	0.06	0.04	0.03	0.97
Average distance to crest	0.40	0.40	-0.29	0.37	0.24
Eigenvalue	1.83	3.38	1.74	2.72	1.31
Percent of total visibility	13	24	12	20	9
Cumulative percent	13	37	49	69	78

Table 4. Linear discriminant function for 5 rotated roost habitat factors.

	Factor	Weights	
		Roost site	Nonroost site
2	Water basin characteristics	1.74	-1.74
1	Surrounding physiography	0.54	-0.54
4	Salinity-vegetation	0.50	-0.50
3	Human disturbance	0.29	-0.29
5	Vegetation height	-0.10	0.10

an F-statistic (Green 1978). There is a highly significant difference between roost sites and nonroost sites (F = 21.2, P < 0.001). Thus, given these factors, cranes are not selecting roost sites on a random basis in this area.

The linear discriminant function is shown in Table 4. It is important for 2 reasons. First, it is used to classify the original ob= servations into 1 of the 2 groups. In this situation, 14 roost and 14 nonroost sites were correctly classified. Secondly, it aids in interpreting which of these factors are most important to the cranes when selecting roost sites. This is done by comparing weights, which indicate that factor's discriminating power.

Factor 2, water basin characteristics, has the greatest discriminating power with a weight of 1.74. Factor 2 is therefore more effective than any other factor in separating roost sites from nonroost sites. High negative factor loadings for Factor 2 are average water depth and bottom slope, and high positive loadings are crane depth and distance to bare shore. A positive weight allows these signs to remain as such, while a negative weight would reverse the signs. Thus, roost sites, with a positive weight, have lower average water depth, higher average crane depth, less steep bottom slope, and greater distance to bare shore than nonroost sites.

The absolute values of the weights for Factor 1 and Factor 4 are nearly equal. Factor 1, surrounding physiography, has a positive weight for roost sites, which means that roost sites have a lower crest and higher visibility indices than nonroost sites. Factor 4, the salinity-vegetation factor, also has a positive weight for roost sites. This factor has a high positive correlation with distance to nearest vegetation, percent area devoid of vegetation, width of bare shore, and conductivity. Therefore, roost sites tend to have larger values for these variables than nonroost sites.

Factors 3 and 5 have much lower discriminating power than the other factors. They both indicate, however, that there is a slight tendency for roost sites to be situated farther from human disturbance and to have lower vegetation height.

DISCUSSION

These data indicate that sandhill cranes roosting in the McLean County staging area are not selecting roost sites randomly or by tradition only. Within the study area, habitat characteristics are important criteria. Tradition may still be a consideration when cranes select the McLean County area over another area, but further study is necessary to test this hypothesis.

Roost sites are distinct from nonroost sites by certain characteristics. Overall, Factor 2 is the most useful for separating roost sites from nonroost sites. The variables it is highly correlated with can be interpreted as being the most important habitat characteristics for roost site selection. These results show that cranes would prefer roost sites with large expanses of shallow water a distance from the bare shore, and with a substrate that is soft. This makes intuitive sense when considering the behavior and gregarious habits of sandhill cranes during fall migration. Cranes often will land on the bare shore or sandbar and walk into the water in the evening, and walk from the water onto the bare shore in the morning. Also, expanses of shallow water allow the cranes to roost together in large numbers.

The next criteria important for separating roost sites are the surrounding physiography and sparse vegetation characteristics associated with high conductivity. The importance of level terrain and good visibility has been suggested by Lewis (1976) in the southern Central Flyway, and by Johnson (1976) in North Dakota, and is confirmed by these data. This visibility is enhanced by sparse vegetation and wide bare shores or sandbars. Roost wetlands sampled by Melvin and Temple (1980) in Kidder County, however, were more visually isolated than roost sites sampled in my study area. Seventy-four percent of their roost sites had complete visual isolation from sources of human disturbance. Only 27% of my roost sites had complete visual isolation from used roads or occupied buildings. Perhaps this difference is simply due to the inherent difference between McLean and Kidder County topography.

The reader should keep in mind that this research and analysis is largely exploratory, useful for generating hypotheses and for consolidating habitat measurements into a more workable form for further studies (Johnson 1981). Caution is necessary in viewing these results. These statistical methods are merely objective ways of viewing sets of multivariate data (James 1971). In this situation, they allow us to observe the unmanipulated variables within this study area. The choice and number of variables, and the location of the study, will obviously affect results and conclusions. There might be other useful factors that I did not consider. Further study in a different area of the Central Flyway would be a strong complement to this study. This information can be suggestive only, for the purpose of evaluating habitat loss or arriving at management schemes, and useful mainly in areas such as North Dakota where roost habitat is not yet very restricted.

Some management implications for McLean County can be suggested. Wetlands with large expanses of shallow water and soft bottom substrates should be given a higher priority for crane habitat over those that have only a limited amount of shallow water. Also, wetlands that have low surrounding physiography and sparse emergent vegetation are better crane habitat than wetlands with steep banks and dense emergent vegetation in shallow areas.

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FOOD CONTENTS OF SANDHILL CRANES DURING WINTER AND SPRING[1]

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Abstract: Three hundred sandhill cranes (*Grus canadensis*) from mid-continental North America were analyzed for food content. Cranes were obtained from western Texas during winter; from Nebraska, Saskatchewan, and Alaska during spring migration; and on the Yukon-Kuskokwim Delta, Alaska, during prenesting. Cereal grains (wheat, barley, corn, and milo) made up over 96% of the aggregate volume of food items from winter through spring migration. The proportion of animal matter in the diet did not increase during any period.

Our purpose is to compare data on food content of 300 sandhill cranes obtained from wintering areas in Texas; migration stops in Nebraska, Saskatchewan, and eastern Alaska; and a nesting area in western Alaska. Previously published studies have been from localized areas and did not evaluate the possible changes in food habits of cranes between wintering and nesting areas. Quantitative information also has not been published concerning food habits of sandhill cranes wintering in western Texas or in Alaska during spring migration and nesting periods.

METHODS

A total of 300 sandhill cranes killed as a result of trapping efforts in Texas and Nebraska, or collected for physiological studies in Canada and Alaska, was analyzed for food contents. Cranes were obtained during January and February 1979, and from November to February 1978-80 near Rich Lake, Terry County, Texas; during March to mid-April in 1979 and 1980 from the Platte River Valley near Hershey, Nebraska; in late April 1980 near Last Mountain Lake, Saskatchewan; and in early May 1980 near Delta Junction in interior Alaska and at Clarence Rhodes NWR in western Alaska.

Cranes were frozen in plastic bags within 5 hours of collection. Later, foods were rinsed from the oral cavity, esophagus, and proventriculus, and the number of individual food items was determined. Contents from the gizzard were not examined because of the limitations of such an analysis as noted by Swanson and Bartonek (1970). Excess water was removed from food items, and volume of each type was determined by water displacement in a graduated cylinder. Data are presented as frequency of occurrence, aggregate volume (percentage of total volume), and aggregate percentage (average of volumetric percentages)(Swanson et al. 1974).

RESULTS AND DISCUSSION

Texas

Cotton and milo are the primary crops in the high plains of western Texas (Murfield et al. 1979). Sandhill cranes from western Texas relied on waste milo as a primary food source (96% of

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Table 1. Food contents of 300 sandhill cranes obtained during winter and spring 1979 in Texas and Nebraska and from late fall to spring 1979-80 in Texas, Nebraska, Saskatchewan, and Alaska.

Location	N	Food item	Frequency of occurrence (%)	Aggregate volume (%)	Aggregate percentage
Texas					
Rich Lake	154	Milo	62.9	96.9	61.3
		Solanaceae	3.2	0.7	0.8
		Corn	0.6	0.4	0.3
		Cotton	1.2	tr[a]	0.2
		Acridae	1.2	0.3	0.2
		Tenebrionidae	2.6	0.2	0.1
		Pentatomidae	0.6	tr	tr
		Carabidae	0.6	tr	tr
		Unidentified invertebrates	1.2	tr	tr
Nebraska					
North Platte	101	Corn	20.8	97.5	19.5
		Alfalfa	6.9	1.1	3.3
		Lumbricidae	9.9	1.1	0.3
		Carabidae	3.9	0.1	0.4
		Acridae	1.0	0.2	tr
Canada					
Last Mountain Lake	15	Wheat	46.7	99.5	46.2
		Carabidae	13.3	0.2	0.3
		Gastropoda	6.7	0.3	0.2
Alaska					
Delta Junction	21	Barley	61.9	98.5	59.8
		Unidentified vegetation	4.8	0.9	1.9
		Carabidae	14.2	0.4	0.1
		Elateridae	4.7	0.1	tr
		Odontidae	4.7	tr	tr
Clarence Rhode NWR	9	Corn-like tubers (Cyperaceae)	22.2	83.6	19.4
		Unidentified vegetation	11.1	14.9	2.2
		Gastropoda	11.1	1.5	0.6

[a] Tr denotes less than 0.1%.

the aggregate volume, Table 1), while cotton seeds were found in only 2 of 154 cranes examined. Complaints of crane depredation in cotton fields of western Texas have recently been filed (H. W. Miller, pers. comm.). The low frequency of occurrence of cotton in the diet of cranes examined in this study suggests that cotton is not an important food source and that widespread depredations of cotton are not very likely to occur if adequate milo stubble is available.

Animal matter constituted less than 1% of the aggregate volume of foods removed from cranes from western Texas (Table 1). All animal foods found in cranes (except Pentatomidae and traces of unidentified invertebrates) from western Texas were from birds collected in November (before the onset of freezing temperatures).

Our results agree with Walkinshaw's (1949) general observations that cranes eat milo in western Texas. However, Guthery (1975) found that sandhill cranes on the Texas Gulf Coast ate primarily native nut-grasses (*Cyperus* spp., over 50% of diet) while milo made up only 6.8% of the volume of foods ingested. Animal matter (12% of diet) was a more important food source on the Gulf Coast where milder winter temperatures probably made animal matter more available than in western Texas.

Nebraska

Waste corn from farming practices in the Platte River Valley was the primary food source (97.5% of the aggregate volume) of cranes staging in Nebraska during spring migration (Table 1). Earthworms were the primary animal food consumed. Farmers in the Platte River Valley believed cranes were helpful in removing potential volunteer corn (W. Maason, pers. comm.), and aerating the soil in alfalfa fields while probing for invertebrates (G. Summers, pers. comm.).

Lewis (1979) found that corn made up 89% of the volume of gullet contents of 45 sandhill cranes collected in the Platte River Valley. Reineke and Krapu (1979) estimated that waste corn constituted 96% of the dry matter intake of cranes staging along the Platte River. The studies of Lewis and Reineke and Krapu parallel the estimated 97.5% aggregate volume of corn found in cranes during this study. Corn is clearly the primary food energy source for cranes staging in the Platte River Valley.

Saskatchewan

Wheat seeds made up over 99.5% of the aggregate volume of foods recovered from cranes collected near Last Mountain Lake, Saskatchewan, during spring migration (Table 1). Stephen (1967) found that grain was present in 93% of 180 sandhill cranes collected in spring and fall 1961-63; wheat was the dominant grain present. Waste grain was eaten during spring migration in Saskatchewan and farmers did not complain about cranes removing such grain (C. Jorgenson, pers. comm.). Wheat was the only vegetative food found in cranes from Saskatchewan during our study and it provided nearly all the nutrient intake of cranes (energy and protein).

Alaska

Barley seeds constituted over 89% of the aggregate volume of foods in sandhill cranes collected near Delta Junction, Alaska, during spring migration (Table 1). Sandhill cranes began using the Delta Junction area recently (Klebesadel and Rested 1981:15). The new Delta Agricultural Project in the Delta Junction area provided an annual grain crop of barley that attracted cranes during spring and fall (Pollack 1981:64). Cranes fed on both waste grain from the previous year (barley stubble fields) and seeds from newly planted barley fields. The agronomic effect of cranes feeding in newly planted barley fields near Delta Junction should receive further study.

Only 3 of 9 cranes we collected on nesting grounds of the Yukon-Kuskokwim Delta in western Alaska had any food items present. Plant material (Cyperaceae and unidentified vegetation) made up 98.5% of the volume of these foods (Table 1). Tubers of Cyperaceae constituted nearly 74% of the aggregate volume of foods ingested by sandhill cranes collected before nest initiation. Little food (plant or animal) was available during this prenesting period due to 80-90% snow cover.

CONCLUSIONS

Cereal grain was the primary food source (over 96% of the aggregate volume) of sandhill cranes wintering in western Texas and passing through Nebraska, Saskatchewan, and interior Alaska during spring migration. Plant materials remain important food items (98% of the aggregate volume) before nest initiation on the nesting grounds in western Alaska. No shift to high protein animal foods was detected between wintering and nesting stages of the annual cycle of sandhill cranes. These data underscore the observation by Iverson (1981) that total protein content of sandhill crane carcasses did not change from early winter to prenesting periods in 1979-80, and suggest the hypothesis that energy is the dominant variable in sandhill crane reproductive and survival strategies. Data from this study also underscore the adaptability of cranes to exploit recent geographic expansion of cereal grain farming, and the importance of small grains in nutrient acquisition by sandhill cranes.

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EXPERIMENTAL RELEASE OF CAPTIVE PARENT-REARED GREATER SANDHILL CRANES AT GRAYS LAKE REFUGE, IDAHO

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Abstract: Eleven captive, parent-reared greater sandhill cranes (*Grus canadensis tabida*) were transported from the Patuxent Wildlife Research Center (PWRC), Maryland, to Grays Lake National Wildlife Refuge (GLNWR), Idaho, and released into the wild on 18 June 1980. Experimental birds included 5 one-year-olds, 2 two-year-olds, and 4 three-year-olds. All individuals were marked with color-coded plastic leg bands and radio transmitters before their release. Prerelease conditioning to barley was accomplished at PWRC and birds were released directly into the wild upon arrival at GLNWR. Information on postrelease behavior, including movements, associations, activity patterns, and social interactions, was gathered by direct observation and radiotelemetry. Although most released cranes soon adopted activity patterns similar to wild birds, they spent proportionately more time foraging and preening, and less time in vigilant behavior than wild cranes. Associations among released cranes were especially apparent with the 2- and 3-year-olds. Although all released cranes interacted with wild cranes, only 1 bird formed a discernible association with a wild individual. Seven released cranes survived to migrate south in October; however, only 1 bird was subsequently located on the New Mexico wintering grounds despite intensive ground and aerial searches. This study suggests that younger cranes are probably better candidates for release programs, and that preconditioning at the release site might increase survival.

In 1975, a program for parent-rearing young cranes in captivity was initiated at the Patuxent Wildlife Research Center, Laurel, Maryland. This parent-rearing program consists of hatching and rearing young cranes in captivity by their natural parents or by foster-parent cranes. The ultimate goal of this program is to produce whooping cranes (*G. americana*) and Mississippi sandhill cranes (*G. c. pulla*) suitable for release into the wild.

Preliminary research suggests that captive cranes reared by natural or foster parents may be better suited for release than are captive, hand-reared cranes. Unlike hand-reared birds which are tame and show little or no fear of man, parent-reared birds remain wild in captivity, and appear better able to adjust to wild conditions following their release. For example, between 1971 and 1976, 17 handreared and 1 parent-reared Florida sandhill cranes (*G. c. pratensis*) from PWRC were released among wild birds near Gainesville, Florida (Nesbitt 1979). Florida sandhill cranes are nonmigratory. The parent-reared bird remained in the vicinity of the release area and was the only long-term survivor from this release (S. Nesbitt pers. comm.). Similarly, a captive, parent-reared greater sandhill crane was released at Grays Lake National Wildlife Refuge, Idaho, among wild subadult greater sandhill cranes in mid-August 1976 without any special prerelease conditioning. This bird joined the wild flock and migrated south on 17 October, but was not seen thereafter.

The present study was undertaken to obtain additional information on reintroduction techniques. The specific goals of this project were: (1) to assess the feasibility of directly releasing captive, parent-reared cranes into the wild with minimal prerelease conditioning; and (2) to compare the behavior, survival rates, and migration success of the released cranes with wild cranes of similar age. Field studies were conducted from June 1980 to August 1981. We especially thank members of the PWRC staff, including Andrew Canine, Jim Carpenter, Elmer Gentry, Steve Leathery, and Bruce Williams for rearing, maintaining, and transporting the birds. Desmond Call, Edward Loth, and Ralph Stoor, GLNWR, assisted us in various aspects of the study. We would also like to acknowledge Keith Day (U.S. Fish and Wildlife Service YACC program, Soda Springs), Caroline Farr, Nancy Gilbertson, Steve Somsen, and Kenneth Walker for their participation in data collection. Ms. Farr summarized portions of the data and wrote a preliminary draft on some aspects of the study. The project was funded by the U.S. Fish and Wildlife Service.

RELEASE SITE

The release site is located in the northwestern portion of the refuge in the Grays Lake Outlet area. The site contains optimum summer and fall habitat for both breeding and nonbreeding sandhill cranes. Annually, some 250-350 cranes summer within 1.6 km of the release site and 600-800 cranes stage in the area during September before initiating fall migration.

The area is bordered on the west by rolling hills covered with sagebrush (*Artemisia* sp.) and grasses. The release site is a large flat consisting of dry and wet meadows which provide feeding and loafing areas for cranes. An extensive bulrush (*Scirpus acutus*)-cattail(*Typha latifolia*) marsh interspersed with ponds lies on the east side of the flats. The marsh provides escape cover and night roosting sites. The only access to the area is over a 3.2-km nonmaintained dirt road. No human habitation exists in the vicinity and human disturbance is minimal.

Refuge personnel annually plant a 9.0-ha field in barley near the release site. The field is periodically baited with supplemental barley to entice cranes and waterfowl to remain on the refuge until private grainfields in the vicinity are harvested. To enhance the survival of the released cranes, their diet was converted from the normal pelletized ration to barley several months in advance of their release. Baiting with barley was continued at GLNWR throughout the postrelease period.

METHODS

On 17 June, the sandhill cranes were brailed at PWRC. On 18 June, they were shipped via airfreight from Baltimore, Maryland, to Salt Lake City, Utah, and then trucked 320 km to GLNWR, where they were released.

Each bird was marked for individual identification with a 7.6-cm-high green plastic leg band with an alpha-numeric code on 1 leg and a blue or white band with an attached radio transmitter on the opposite leg. Bands were placed above the tibio-tarsal joints to enhance visibility and signal transmission.

Radio transmitters in the 164-MHz frequency range were purchased from Telemetry Systems, Inc. (P. O. Box 187, Mequon, Wisconsin 53092) and Telonics Inc. (1300 W. University, Mesa, Arizona 85201). Telonics transmitters were powered by batteries and Telemetry Systems transmitters were powered by batteries supplemented with solar cells. Weights of radio packages (plastic leg band and transmitter) were 45-65 g for the solar and small battery units, and 65-70 g for the larger battery-powered units. Antennas were 21-24 cm long and extended down the bird's leg. Battery-powered transmitters were attached to the plastic leg bands with small screws and the solar-powered transmitters were epoxied to plastic leg bands.

Information was gathered on released cranes by observation and radio tracking. Crane movements were monitored with Telonics scanning receivers (Model TR-2, Scanner/Programmer Model TS-1), and nondirectional whip and directional yagi antennas. Birds were observed with binoculars and spotting scopes. Most observations were conducted from a blind located adjacent to a refuge grainfield near the release site. In other instances, cranes were observed without cover or from a vehicle. Most observation periods were confined to morning and evenings when cranes were foraging in or near the refuge grainfield or in other open areas.

Data recorded included movements, mortality, time budget information on activity patterns, association with other cranes, incidences of aggressive encounters, and migration. Associations were determined from the number of occurrences when Patuxent birds were observed together or in company with other cranes. An association was counted again if at least 15 minutes had elapsed since it was 1st recorded. Records of agonistic encounters included the aggressor, the attacked bird, manner of attack, response of the attacked bird, and the outcome. Time budget data were collected by coded behavioral point counts. To provide a comparison, time budget data were also collected on the activities of 10 color-marked wild cranes frequenting the release site. These birds were captured as flightless young at Grays Lake between 1977 and 1979 and included 2 three-year-olds, 5 two-year-olds, and 3 one-year-olds.

Migration success of the released cranes was assessed by surveying fall and spring stopover sites in Colorado and wintering areas in the Southwest. From late October to mid-November, and again in March and early April, ground surveys employing radiotelemetry were conducted in the San Luis Valley, Colorado, the major fall and spring migration stopover area for cranes summering at Grays Lake NWR (Drewien and Bizeau 1974). All principal crane wintering areas in New Mexico, southeastern Arizona, Muleshoe NWR in Texas, and northwestern Chihuahua, Mexico, were surveyed by ground or air from November 1980 to February 1981.

Observations of the 10 color-marked wild cranes frequenting the release site and used in the time-budget analysis were also recorded along the migration route and on wintering areas. These sightings were used to compare the migration success of wild cranes versus released cranes, and provided insight into the thoroughness of our surveys along the migration route and on winter areas.

Table 1. Greater sandhill cranes released at Grays Lake NWR on 18 June 1980.

Identification no.	Age	Sex	Release group	Parental origin[a]
T19	3	M	1	MNWR
T20	3	M	1	BDANWR
T21	3	F	1	GLNWR
T22	3	M	1	GLNWR
T23	2	M	2	GLNWR
T24	2	M	2	GLNWR
T25	1	M	2	GLNWR
T26	1	M	3	MNWR
T27	1	F	3	BDANWR
T28	1	M	4	GLNWR
T29	1	M	4	MNWR

[a] Released birds were derived from Malheur National Wildlife Refuge (MNWR), Oregon; Bosque del Apache National Wildlife Refuge (BDANWR), New Mexico; and Grays Lake National Wildlife Refuge (GLNWR), Idaho.

RESULTS

Release of Patuxent Cranes

Twelve cranes arrived at the release site at 1815 hours, 18 June. One bird died in transit, possibly from stress related to the long 17-hour trip. The remaining 11 cranes--all derived from western populations of greater sandhill cranes (Lewis 1977)--were banded, color-marked, radio instrumented, and released in 4 groups (Table 1). Birds were released in small groups due to the delay in processing individuals and to their late arrival in the day. The last group was released at 2115 hours. Ten birds walked or ran and 1 flew about 200 m to a nearby wetland where they all stopped to drink. They then moved east toward the marsh and disappeared into emergent vegetation.

Movements

All transmitters functioned well until 5 August when a Telonics radio on T22 failed. It was later determined that the transmitter (attached with screws) dropped off the plastic leg band. We believe the transmitter fell off T22 while he was in the marsh because a signal was never received after this date. Telonics transmitter on T24 failed for unknown reasons on 3 September.

Eight cranes remained in the immediate vicinity of the release site (Table 2). Most foraged twice daily in the refuge grainfield, returning to Outlet Flats during the middle of the day and to the marsh at night, a distance of about 1 km (Fig. 1). Six of these birds (T20, T21, T22, T23, T24, and T28) survived and regularly fed in the refuge grainfield until early September (Table 2).

On 3 September, T23 and T28 moved with several hundred wild cranes to feed in private grainfields about 7 km north of the release site (Fig. 1, Table 2). Movements of T24 following transmitter failure could not be followed closely; however, this bird was observed with T23 and T28 on 15 September and we believe that all 3 birds remained together continuously following release. From 5 to 11 September, T23 and T28 (and presumably T24) fed in private grainfields each day, and roosted nearby in the Grays Lake Outlet each night. Although all 3 birds returned to the Grays Lake marsh to roost each night after 16 September, they did not return to the release area and refuge grainfield until 26 September. After this date, T23, T24, and T28 remained in the release area until they migrated south.

T20, T21, and T22 remained in the release area until 22 September, when they also moved north to feed in private grainfields. They returned to the release area to roost nightly. Over 600 sandhill cranes were feeding in these private grainfields on 22 and 23 September. By 24 September, T20, T21, and T22 returned to the release area (Table 2) and resumed feeding in the refuge grainfield until they migrated.

Three birds left the release site soon after they were liberated on 18 June. Two (T19, T25) moved 2.9 km to South Drainage (Fig. 1). T19 was last observed near the release site on 20 June, and T25 on 26 June. Both birds were located in South Drainage on 27 June (Fig. 1, Table 2) where they remained.

A 1-year-old female, T27, moved the greatest distance during summer (36.1 km), but remained in Grays Lake Basin. On 20 June, T27 moved west from the release site across the west road and continued to wander in sagebrush hills to the southwest (aspens west of road, Fig. 2). On 21 June, she flew southeast from the sagebrush hills back across the road to South Drainage, a distance of 3.5 km (Fig. 2, Table 2). The bird returned west of the road on 22 June, traveling 2.9 km to Cow Camp. On 23 June she was found feeding with a scattered group of 7 sandhills on marsh flats (West Flats, Fig. 2) east of Sharp Curve and 3.4 km from Cow Camp (7.9 km south of the release site).

Radio signals indicated that T27 remained in the vicinity of Sharp Curve from 23 June to 24 August but she was rarely observed. Through mid-July, most radio signals were received from the

Table 2. Movements of Patuxent sandhill cranes released at Grays Lake NWR, 18 June 1980.

Bird identification number	Location	Movement distance (km)	Dates present
T20, T21, T22	1. Release site	--	18/6 - 22/9
	2. Private grainfields north of release site	6.8 north	22/9 - 23/9
	3. Release site	6.8	24/9 - 06/10
		13.6	
T23, T24, T28	1. Release site	--	18/6 - 03/9
	2. Private grainfields north of release site	6.8 north	03/9 - 26/9
	3. Release site	6.8	26/9 - 06/10
		13.6	
T19	1. Release site	--	18/6 - 21/6
	2. Unknown		22/6 - 26/6
	3. South Drainage	2.9	27/6 - 30/7
	4. Found dead		31/7
T25	1. Release site	--	18/6 - 26/6
	2. South Drainage	2.9	27/6 - 30/7
	3. Found dead		31/7
T26	1. Release site	--	18/6 - 29/7
	2. Found dead	0.0	30/7
T29	1. Release site	--	18/6 - 01/8
	2. Found dead	0.0	02/8
T27	1. Release site	--	18/6 - 20/6
	2. Aspens west of road	3.7	20/6 - 21/6
	3. South Drainage	5.3	21/6
	4. Cow Camp	2.9	22/6
	5. West flats	3.4	23/6
	6. Reservoir area	4.2	12/8 - 24/8
	7. Grainfield A	13.1	25/8 - 27/8
	8. Grainfield B	0.8	27/8 - 03/9
	9. Grainfield C	2.7	03/9 - 09/10
		36.1	

extensive West Flats (Fig. 2) where over 100 sandhills summered and foraged daily in tall, dry meadow vegetation which minimized opportunities to observe colored leg bands. After mid-July, radio signals were received sporadically from the hills northwest of Sharp Curve.

T27 was not sighted until the evening of 11 August when she was observed flying east from the hills with 1 sandhill to roost in Grays Lake marsh east of Sharp Curve. The following day, T27, accompanying a wild male, and another pair were located on a ridge 0.5 km southeast of Reservoir Area (Fig. 2). The 4 cranes were flushed and T27 followed the male east toward Grays Lake, both landing about 300 m east of Sharp Curve.

On 25 August, T27 was located in grainfield A on the southeastern side of the refuge, 13.1 km from Reservoir Area (Fig. 2). On 27 August, T27 moved a short distance north to refuge grainfield B, and on 3 September she moved north again to the vicinity of refuge grainfield C where she remained until migrating south.

Mortality

Four of 11 released cranes died during the summer: 3 one-year-olds (T25, T26, and T29) and 1 three-year-old (T19) [Table 2]. The remains of T19, T25, and T29 were located on 31 July,

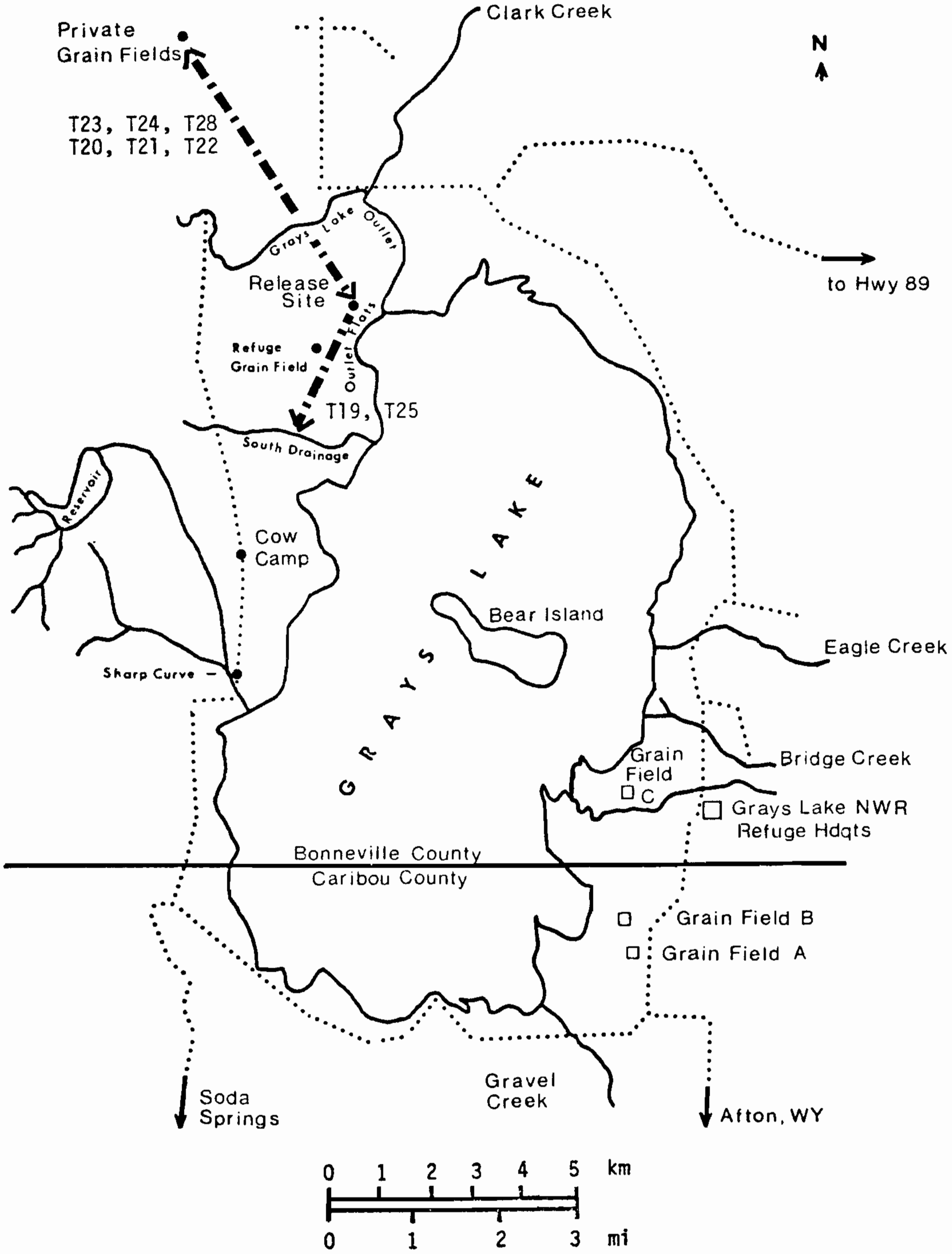

Fig. 1. Movements from 20 June to 5 October 1980 of 8 Patuxent sandhill cranes released 18 June at Grays Lake NWR, Idaho.

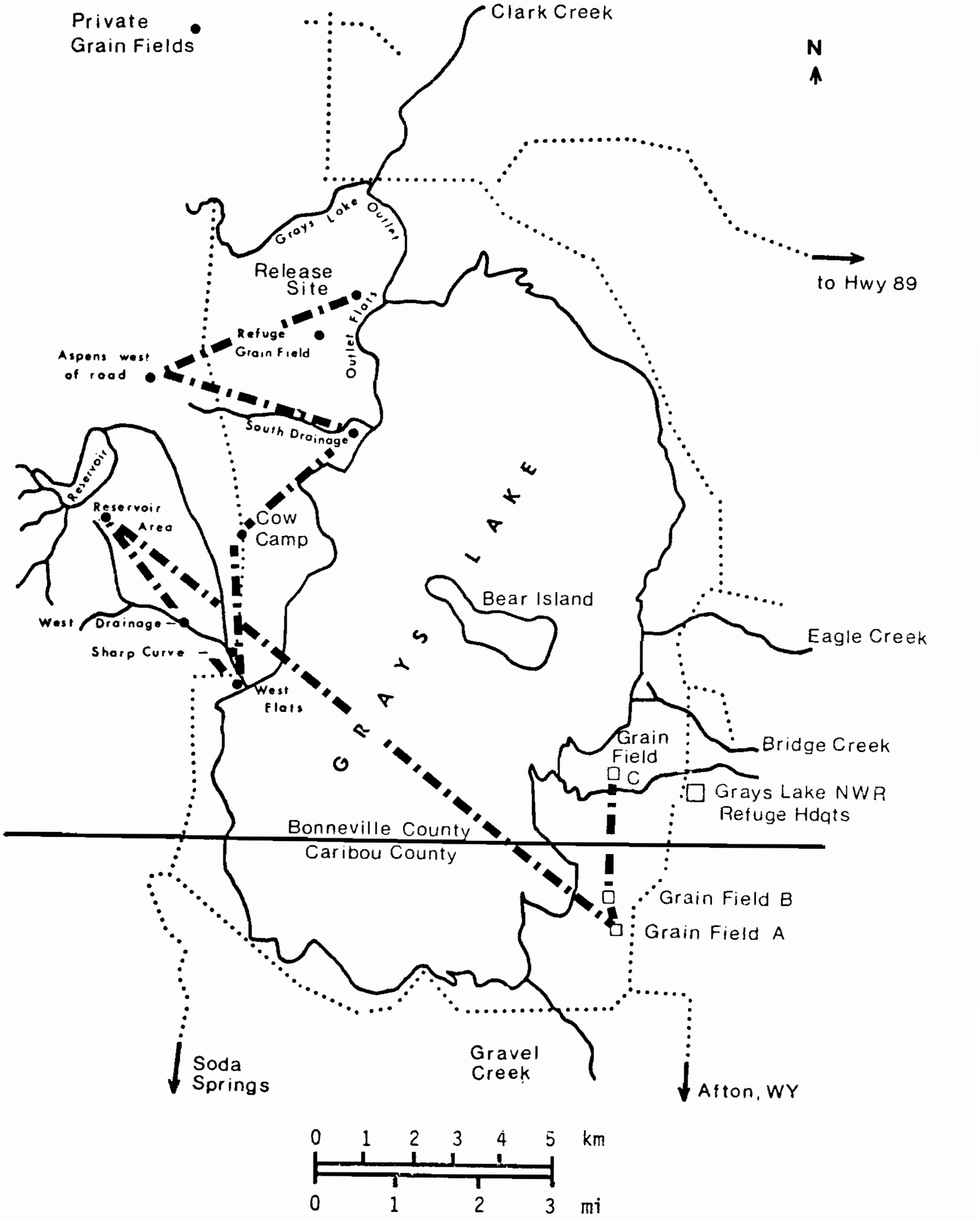

Fig. 2. Movements of Patuxent sandhill crane, T27, from 20 June to 9 October 1980, released at Grays Lake NWR, Idaho, 13 June 1980.

31 July, and 2 August, respectively. Although the cause of death could not be ascertained for any of these cranes, we suspect that 2 (T19, T25) may have starved to death. T19 and T25 were never observed feeding in the refuge grainfield, and apparently foraged exclusively on natural foods available in the dry meadows near the release site.

T29 was never observed after release, although radio signals were received sporadically from Outlet Flats. On 2 August, T29 was found buried in a badger hole except for its legs which protruded from the hole entrance. Very little of the carcass remained, and cause of death could not be determined.

The remaining bird, T26, was found dead on 30 July. Severe cranial wounds suggested that this bird had been killed by a wild crane. On 20 July, an unidentified 1-year-old PWRC crane was observed during an aggressive encounter with a wild sandhill crane on Outlet Flats. Even though the released bird retreated and made no attempt to fight back, he was chased and repeatedly pecked on the back of the head. This observation and similar ones made in captivity support our belief that the wounds found on the head of T26 were inflicted by a wild crane.

General Activity Patterns

During summer and fall, wild cranes in the release area normally fed twice daily, morning and evening, at the refuge grainfield. During midday hours, cranes mainly occupied Outlet Flats and at night moved to the marsh to roost (Fig. 1). Cranes fed on barley in the grainfield; on Outlet Flats they foraged on natural foods, preened, and rested. All daily requirements and habitats utilized by the PWRC and wild cranes in the release area, including night roost sites, meadow loafing and feeding sites, and the grainfield, were located within 130 ha. The maximum distance between major habitat components utilized by the cranes during their daily activity patterns was about 1 km. This routine was followed daily until fall migration by most Patuxent and all wild sandhills in the release area except for a period in September when the birds temporarily vacated the area and moved north to feed in private grainfields.

Six (T20, T21, T22, T23, T24, and T28) of 8 Patuxent cranes which remained at the release site quickly adopted the daily activity patterns of wild sandhills. Only 2 Patuxent birds (T26, T29), which remained at the release site and later succumbed, failed to adjust to this pattern. Bird T29 was never observed at the refuge grainfield and T26 was observed on only 3 occasions (7, 11, and 12 July).

Little is known about the daily activity patterns of the 3 cranes (T19, T25, and T27) which departed from the release area; only T27 survived. However, the 3 were not observed in the refuge grainfield before their departure from the release site, nor was any supplemental food in the form of grain available in areas where they relocated.

Compared to wild cranes, activities of T27 were very atypical for a few days after her release. During the morning of 20 June, T27 wandered along westward into the sagebrush-grass uplands where she roosted that night. By the following morning she was 3.7 km southwest of the release site (Table 2, Fig. 2) walking aimlessly in the hills. She finally flew southeast toward the marsh on 21 June and continued moving south, roosting that night in a thicket along a small intermittent drainage. On 22 June, T27 moved to the West Flats near Sharp Curve (Fig. 2) and again roosted alone in a ditch that night. The following morning, 23 June, T27 finally joined a group of subadult sandhills at West Flats and remained in that vicinity for the next 2 months. She adopted the activity patterns of a wild bird which she accompanied.

Time Budgets

Data were collected to determine how Patuxent cranes spent their time and to compare their schedules with those of wild birds. Because time budget information was obtained from a blind at the refuge grainfield, only those activities observed while birds were at the grainfield are represented. Undoubtedly, activities on the Outlet Flats and in the adjacent marsh would differ somewhat from those observed at the grainfield. A total of 5.5 hours of data were collected for 6 birds (T21, T22, T23, T24, T25, and T28) in June and 5.7 hours for 6 birds (T20, T21, T22, T23, T24, and T28) during July and August. In addition, 7.5 hours of activities were recorded for 10 wild color-marked cranes.

Time budget data for Patuxent cranes were divided into 2 periods for analysis. A convenient separation occurred between 28 June and 6 July when no information was collected. Data points were also collected at different time intervals (30 seconds versus 15 seconds) during the 2 periods. Separation of the data provided a comparison between the period immediately following release and a later period after the Patuxent cranes had an opportunity to adjust to wild conditions.

Chi-square analysis indicates a highly significant difference ($P < 0.001$) in the time distribution of activities by Patuxent and wild cranes. These differences were most marked in the categories of standing-alert, preening, and walking (Table 3). While in the grainfield, both Patuxent and wild cranes spent most of their time feeding, with Patuxent cranes expending a little more time eating than wild birds. The 2nd ranking activity of cranes in the grainfield was standing-alert behavior (Table 3). When 1st released, Patuxent cranes spent only 9% of their time alert to what was going on around them; during July-August vigilant behavior increased to 18% of their activities. In contrast, wild cranes spent 29% of their time in this activity.

Wild cranes and Patuxent cranes when released in June spent an equal amount of time preening (Table 3). Patuxent birds, however, increased their preening activity in July and August to more than twice the rate of wild birds. Along with normal feather preening, Patuxent cranes were also observed manipulating plastic leg bands, radio transmitters, and especially transmitter antennas with their bills. This activity decreased in July and August as birds became more accustomed to the bands and transmitters (Table 3). Following release, Patuxent cranes spent nearly 21% of their time walking around in the grainfield. This activity decreased to 6% in July and August, very close to the 8% observed for wild cranes (Table 3). All other activities, including running, flying, and calling, took less than 5% of the birds' time (Table 3).

Table 3. Comparison of time spent (number of data points) in various activities by Patuxent sandhill cranes and 10 wild sandhill cranes at Grays Lake NWR, Idaho, June-August 1980.

	Patuxent cranes[a]				Wild cranes (N = 10)[b]	
	19-27 June		7 July - 17 August			
Activity	Data point	%	Data point	%	Data point	%
Foraging	407	62.2	838	61.5	1,028	56.9
Standing-alert	59	9.0	247	18.1	480	26.6
Preening	29	4.4	150	11.0	98	5.4
Preening radio antenna	10	1.5	10	0.7	--	--
Other comfort movements	8	1.2	26	1.9	21	1.2
Walking	135	20.6	82	6.0	138	7.6
Running	0	0.0	1	0.1	2	0.1
Flying	0	0.0	1	0.1	6	0.3
Aggression	0	0.0	2	0.2	5	0.3
Submission	3	0.5	2	0.2	7	0.4
Calling	0	0.0	3	0.2	2	0.1
Other	3	0.5	0	0.0	19	1.1

[a] Marked cranes in 19-27 June observation period included T21, T22, T23, T24, T25, and T28, and during 7 July - 17 August observation period T20, T21, T22, T23, T24, and T28. Data points were collected at 30-second intervals from 19-27 June, and at 15-second intervals from 7 July to 17 August.

[b] All 10 wild cranes were individually color-marked as chicks at Grays Lake NWR between 1977 and 1979.

Table 4. Associations of Patuxent sandhill cranes at Grays Lake NWR, Idaho, 18 June-5 October 1980.

Identification of Patuxent birds in groups	Frequency N	Frequency %	Identification of Patuxent birds in groups	Frequency N	Frequency %
T20, T21, T22	27	24.5	T22, T23, T24	2	1.8
T23, T24	24	21.8	T21, T22, T23, T24	2	1.8
T23, T24, T28	12	10.9	T20, T24	1	0.9
T20, T21, T22,			T21, T28	1	0.9
T23, T24, T28	10	9.1	T22, T24	1	0.9
T20, T22	8	7.3	T22, T23, T28	1	0.9
T24, T28	4	3.6	T20, T21, T22, T28	1	0.9
T21, T22	3	2.7	T20, T21, T23, T28	1	0.9
T22, T23	3	2.7	T20, T23, T24, T28	1	0.9
T20, T21	2	1.8	T20, T22, T24, T28	1	0.9
T22, T28	2	1.8	T20, T21, T22, T23, T24	1	0.9
T23, T28	2	1.8	Total groups	110	99.7

Associations

Two-thirds of all observed associations of the 6 Patuxent cranes which survived and remained near the release site were confined to 4 groups: (1) three 3-year-olds, T20, T21, and T22; (2) two 2-year-olds, T23 and T24; (3) two 2-year-olds and a 1-year-old, T23, T24, and T28; and (4) all 6 birds together. Remaining associations occurred in 18 different groupings (Table 4).

T26, a 1-year-old that later died, was observed with another Patuxent bird (T24) on only 1 occasion. The 3 other Patuxent cranes which died during the summer (T19, T25, and T29) were not observed associating with any other cranes.

T28, a 1-year-old, had a much stronger affiliation with the 2-year-olds than the 3-year-olds, but this association was not as pronounced as that of the 2-year-olds for each other (Table 4). T28 became more closely associated with the 2-year-olds in the 2nd month after release. Observatons revealed that the 3-year-olds were strongly associated with each other. The 2-year-olds were also strongly associated with each other.

The 2 major groups (T20, T21, T22, and T23, T24, T28) associated with each other, but not strongly, until just before migrating. Excluding the period 30 September-5 October, the 6 birds were only observed together on 2 other occasions, both in August. However, after many wild cranes migrated from the release area in late September, the 6 birds stayed together except for short periods when 1 or 2 individuals temporarily moved some distance away.

Female T27, a 1-year-old which left the release site, associated only with wild cranes; she was observed on 3 occasions accompanying a wild male. Except for T27, there was no indication that any of the other Patuxent cranes associated with individual wild cranes for any extended period. Forty-nine different color-marked wild cranes were identified between June and September near the release site. Most Patuxent birds were observed in the company of both marked and unmarked wild birds, but no lasting associations developed.

Agonistic Behavior

Attacks, submission, and retaliation occurred in a variety of forms. An attacking crane might threaten or stab at another bird with its bill without moving nearer, or it might walk or run a short distance to do so. Occasionally, long chases occurred. An attacked crane might maintain its position, walk, run, fly away, or fight back. When a bird retreated, it sometimes returned quickly to the area initially occupied. When defending themselves, cranes fought with their bills, wings, and toenails; often they fought only with their bills, but at other times with a combination of the above.

Observations of Patuxent cranes during the period immediately following release showed that they were submissive, tended to avoid aggressive encounters, and remained at the edges or away from the wild flock while feeding in the refuge grainfield. On 22 and 25 June, T20, T21, and T22 walked around the periphery of a flock in the grainfield and fed some distance away. On 23 June, T24 was chased by a wild sandhill while feeding and flew from the grainfield. Cranes T20 and T22 fed among wild cranes on 27 June, but left the grainfield after being attacked. Younger birds (T23, T24, and T28) fed among wild cranes earlier than the 3-year-olds (T20, T21, and T22), but when attacked ran to the edges of flocks. By mid-July, Patuxent cranes were observed regularly mixing with wild cranes.

Overall, Patuxent birds lost far more encounters with wild cranes than they won. Between 20 June and 30 September, 79 aggressive encounters were recorded involving Patuxent birds; Patuxent birds won 20 and lost 59 (Table 5). Generally, the aggressor won the encounter. In the 20 instances where Patuxent cranes won, they initiated 18 of the encounters. In contrast, in 61 instances where Patuxent birds were recipients of aggression, they lost 59 times.

Patuxent cranes exhibited increasing aggression toward other cranes as they spent more time in the wild. Before 26 July, Patuxent birds initiated 5 attacks; after 26 July they were observed initiating 15 attacks.

Most encounters between wild and Patuxent cranes were relatively mild. In most instances, a bird would threaten or peck another and the recipient would retreat. Among 79 recorded encounters, only 5 involved fighting or potentially serious body contact.

Fall Migration

Cranes annually gather each fall at 2 staging areas in Grays Lake Basin before migrating; in the vicinity of the release site in Grays Lake Outlet area, and in the southeastern portion of the refuge between Gravel and Eagle Creeks (Fig. 1). Six Patuxent birds remained at the Outlet staging area, and 1 bird (T27) moved to the southeastern staging area in late August (Fig. 2).

The 1st crane observed migrating from Grays Lake left on 24 September. Large numbers departed from the outlet staging area during the last few days of September and in early October. By 4 October, only 11 sandhills (including the 6 Patuxent birds) and 1 whooping crane remained in the area (Table 6).

Crane migrations were monitored daily from 1030 to 1330 hours during early October. Most cranes normally initiate migratory flights during midday hours. By 1330 hours, 5 October, 11 sandhills, including 6 Patuxent birds, and the whooping crane were at the outlet staging area. At approximately 1400 hours, after daily monitoring had terminated, the whooping crane and 5 sandhills were observed leaving (by Refuge Manager E. Loth) and were followed by a 2nd group of 6 sandhills. Presumably, the 5 sandhills in the group with the whooper were the wild cranes and the 2nd flock of 6 were Patuxent birds. Subsequent radio searches and visual surveys confirmed that the Patuxent cranes departed Grays Lake during the afternoon of 5 October.

Crane T27 migrated from the southeast staging area on 9 October. Before leaving, T27 made a preliminary migration start on 6 October; false migration starts are common among wild sandhills we have observed at Grays Lake. At 1229 hours, 6 October, T27 joined several hundred sandhills in a soaring flight some 800-1,000 m above the valley. Some cranes in the flock migrated while others, including T27, returned to the refuge; T27 landed at 1253 hours.

At 1134 hours, 9 October, T27 joined a flock spiraling upward on late morning thermals. A flock of 28 cranes, including T27, left Grays Lake in a southeasterly direction at 1202 hours, flying at an estimated altitude of 1,000-1,300 m above the valley floor.

Crane T27 was located on 28 October near the south boundary of Monte Vista National Wildlife Refuge, Colorado. T27 was associating with a wild sandhill, possibly the same male she accompanied at Grays Lake. She remained in the area through 15 November. The other 6 PWRC cranes were not located in the San Luis Valley.

Subsequent Observations

Only 1 of the released cranes, female T27, was located on the wintering grounds. She spent the winter in the central Rio Grande Valley at and in the vicinity of the Bosque del Apache National Wildlife Refuge, New Mexico, the principal wintering area for sandhill cranes from Grays Lake

Table 5. Aggressive encounters between Patuxent sandhill cranes and wild sandhill cranes at Grays Lake NWR, Idaho, 20 June - 30 September 1980.

Patuxent crane identification number	Won	Lost	Total
T19[a]	0	0	0
T20	0	8	8
T21	0	4	4
T22	3	12	15
T23	4	7	11
T24	4	8	12
T25	1	3	4
T26	0	1	1
T27[a]	0	0	0
T28	5	7	12
Unidentified 3-year-old	2	5	7
Unidentified 2-year-old	0	2	2
Unidentified 1-year-old	0	1	1
Unidentified - Unknown age	1	1	2
Total	20	59	79

[a] Birds T19 and T27 were never observed in aggressive encounters.

Table 6. Numbers of cranes staging before fall migration in the Grays Lake outlet area and chronology of fall migration, September-October 1980.

Date	Wild sandhill cranes	Patuxent cranes
10 September	566	6
23 September	642	6
29 September	296	6
30 September	162	6
1 October	111	6
2 October	64	6
3 October	35	6
4 October	5	6
5 October	5	6
6 October	7	0
7 October	0	0
8 October	0	0

(Drewien and Bizeau 1974). Repeated observations indicated that T27 had fully integrated with the wild sandhill cranes which she accompanied. T27 was last observed in March 1981 during the northward migration on and near the Monte Vista National Wildlife Refuge in the San Luis Valley, Colorado; at that time we observed that the antenna of the radio transmitter was missing, and consequently the signal could only be received at close range.

Intensive searches of major summering areas used by subadult cranes originating from Grays Lake in eastern Idaho, western Wyoming, and southwestern Montana have not revealed the presence of T27 or any of the other 6 released cranes, and consequently their fate at present remains unknown. We are currently monitoring fall migration staging areas in order to relocate these birds, and will continue to conduct surveys at the major migration stopover in the San Luis Valley and at traditional wintering areas in the Rio Grande Valley during the fall and winter of 1981-82.

In comparison, 9 of 10 wild, color-marked cranes which frequented the release site were relocated between November 1980 and August 1981. Eight of these birds were observed along the migration route and on winter areas. Another individual was observed back at the release site during the 1981 summer. Therefore, only 1 of the original 10 wild cranes used as controls has not been relocated since the 1980 fall migration from Grays Lake.

DISCUSSION

Seven of 11 captive parent-reared cranes released at Grays Lake NWR on 18 June 1980 survived to migrate in early October. Among 4 birds which died during the summer, 2 left the release site and did not associate with either wild cranes or Patuxent cranes. Two other cranes that died remained near the release site, fed in the refuge grainfields rarely, if at all, and associated with few cranes. In contrast, surviving cranes associated with other cranes and fed regularly in the refuge grainfield. The only crane that left the release site and survived was a female; this bird was observed in company with a wild male and other wild sandhills.

These findings suggest that captive parent-reared cranes released at Grays Lake had to associate with other birds or eat regularly at the refuge grainfield to survive. If bird T27 had remained alone, it is unlikely that she would have survived. Being a female may have added to T27's chances for survival because she was probably more likely to be found and selected by a wild male. The male

PWRC cranes, being largely dominated by wild cranes during the 1st weeks of release, would probably be less likely to be selected or accepted by wild females during that critical period.

Six of 7 cranes which survived remained in the vicinity of the release site. These birds quickly adopted the daily activity patterns of wild cranes, although they allocated more time to feeding and less time to vigilant behavior than their wild counterparts. During July and August, the released cranes spent much more time preening than wild birds. Possibly, preening activity was a displacement behavior to avoid aggressive encounters with wild cranes. The reduced vigilance of the released cranes can probably be attributed to their previous life in captivity where food was always provided and alertness was not needed to avoid predators.

Younger cranes (1- and 2-year-olds) joined and associated with wild flocks earlier than the 3-year-olds. They were also observed joining wild cranes in early September to feed in private grainfields north of the refgue. In contrast, the surviving 3-year-olds were almost always together and often by themselves some distance from groups of wild cranes. The trio of 3-year-olds did not leave the release site until all wild cranes shifted to feeding in private grainfields in late September.

The strong association among 3-year-olds (T20, T21, and T22) for each other and the group of 2-year-olds (T23, T24) is understandable because they had ample time to form bonds at Patuxent. The 3-year-olds, including T19 which died during the summer, had been kept together since August 1978. After their release, only T19 remained alone and failed to associate with its former pen mates. The two 2-year-olds had also been confined together since July 1978. The association between the 1-year-old, T28, and the 2-year-olds cannot be explained by their relationships at Patuxent. Why the 1-year-old joined the 2-year-olds and all 6 Patuxent cranes gathered together before migration is uncertain. It appears that the 6 Patuxent birds never completely integrated with wild cranes even though they were observed mixing with them throughout the summer and in early fall. Only the 1-year-old, T27, developed associations with and completely integrated into the wild flock.

It is interesting that none of the 1-year-olds developed any group associations with each other after the release as was observed among 2- and 3-year-olds. All 1-year-olds released at Grays Lake were initially removed from their parents at Patuxent on 26 October 1979 and placed together in a flight pen. Due to aggression between individuals, the birds were divided into 2 groups on 8 November. Cranes T25, T26, T27, and T29 were left together and crane T28 and the bird which died in transit to Grays Lake were placed in another pen until they were released in June. The opportunity for bonds to develop between 4 birds (T25, T26, T27, and T29) existed, but apparently did not occur.

Strong ties between individual cranes probably do not develop during their 1st year of life. Presumably some mechanism operates to prevent the development of strong associations; otherwise siblings in 2-chick broods might develop bonds for each other. Repeated observations of hundreds of wild 2-chick broods color-marked in the vicinity of Grays Lake indicate that associations between siblings are extremely rare after thay are 1 year old.

Based upon the small samples of birds in the 3 age groups, the data suggest that younger birds are probably better candidates for release programs. They would have less time to become permanently accustomed to captivity and to each other. The 1- and 2-year-old cranes that survived appeared to intermingle with wild cranes more successfully than the 3-year-olds. One-year-olds, which have not formed bonds with each other, appear to be better suited for release programs where it is desired to add members to the nonbreeding cohort. If experimental releases of paired sandhill cranes are planned, 2-year-olds would appear to be good candidates because they would have time to establish bonds before release and they seem to intermingle more readily with wild birds. A period of conditioning in flight pens at the release site might aid in reducing mortality; all losses occurred in the first 5 weeks in this study. Preconditioning in pens at the release site might also provide cranes with the opportunity to adjust to local conditions, food supplies, and the presence of wild birds in the vicinity; the released birds might then be more likely to remain near the release site.

Although 7 of 11 parent-reared cranes released directly into the wild at Grays Lake Refuge survived the summer period, only 1 of these birds successfully migrated to the wintering area normally used by the Rocky Mountain population of greater sandhill cranes (Drewien and Bizeau 1974, Lewis 1977). Even though the other 6 parent-reared cranes associated with wild birds, they never completely integrated into the wild flock, and subsequently migrated by themselves to an undetermined location. These findings suggest that parent-reared cranes must become fully integrated into the wild flock if they are to successfully migrate to traditional wintering areas. Additional investigations are needed to determine how such social integration can be facilitated following release, so that captive-reared individuals can learn appropriate migratory patterns from their wild conspecifics.

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GENTLE RELEASE OF CAPTIVE, PARENT-REARED SANDHILL CRANES INTO THE WILD

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Abstract: Nine captive, parent-reared Mississippi sandhill cranes (*Grus canadensis pulla*) were transported from Patuxent Wildlife Research Center to the Mississippi Sandhill Crane National Wildlife Refuge and released to augment the native sandhill crane population. The birds were physically examined, treated with an anthelminthic, and wing-brailed before shipment. Leg-mounted radio transmitters, and color-coded plastic and numbered aluminum leg bands were placed on each bird before they were released in a 2-ha release enclosure. Behavior of the penned birds was observed and recorded during daylight hours. After about 6 weeks of acclimation the birds were recaptured and their wing brails were removed. Behavior within and outside of the pen subsequently was observed and recorded. Movements were monitored using radiotelemetric fixes. All birds survived the first 5 months after release. Continued monitoring will assess survival and acceptance into the native population.

In 1975, the Patuxent Wildlife Research Center (PWRC), Maryland, initiated a program in which selected pairs of greater (*Grus canadensis tabida*) and Florida (*G. c. pratensis*) sandhill cranes were permitted to hatch and raise young. Parent-reared birds are generally considered suitable for release into the wild; consequently, this parent-rearing program was aimed at preparing these surrogates to hatch and rear whooping cranes (*G. americana*) and Mississippi sandhill cranes. Naturally, the success of any release program depends ultimately on the number of birds which adapt to their new environment and survive to reproduce.

Few attempts have been made thus far to release captive-reared cranes into the wild. Between 1971 and 1975, 18 Florida sandhill cranes raised at PWRC were released in suitable habitat near Gainesville, Florida. Seventeen of these birds were hand-reared, and 1 was parent-reared (Nesbitt 1978). Twelve parent-reared greater sandhill cranes raised at PWRC were released at Grays Lake National Wildlife Refuge, Idaho, 1 in 1976 and 11 in 1980 (Drewien and Bizeau 1980). Unfortunately, these translocation experiments have met with limited success. This paper reports on a "gentle" release technique used to translocate parent-reared Mississippi sandhill cranes, and compares the initial success of this technique to those techniques used in the aforementioned studies.

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RELEASE SITE

A secluded area on the MSCNWR was chosen for the release. The access road to the release area is controlled by locked gates which minimize the possibility of human disturbance. Within the release area, a 2-ha predator-proof acclimation pen was constructed on a natural wet savanna contiguous to a series of historical nesting and feeding areas. The northern third of the pen and the sloping upland area adjacent to the north and west side of the pen were prepared as a crop field. Two feed sheds with hanging feeders containing pelleted feed and shelled corn were placed in the northeast and northwest quadrants of the pen. The feedsheds, hanging feeders, and food items were

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[1] Louisiana State University, Louisiana Department of Wildlife and Fisheries, U.S. Fish and Wildlife Service, and Wildlife Management Institute cooperating.

identical to those available to the birds at PWRC before shipment. Shelled corn was also scattered on the ground in the vicinity of the feeders to simulate a cultivated field. A small drain flowing from the sloping uplands was ditched and diverted into the release pen to provide a source of water and aquatic food.

The remainder of the pen was not disturbed. Vegetation in the undisturbed area consists of marsh grasses (*Aristida* spp., *Tenium aromaticum*, and *Xyris* spp.) interspersed with bald cypress (*Taxodium distichum*). Grasses provided potential escape cover and night roosting sites and the trees provided shade. The area surrounding the pen consists of slash pine (*Pinus elliottii*) forest, natural savanna, and swamp. Native plants found in the area were listed by Valentine and Noble (1970).

METHODS

Between 1965-77, eggs were removed from Mississippi sandhill crane nests in Jackson County, Mississippi, and transported to PWRC to establish a captive flock. The ultimate goal of this propagation program is to produce stock for augmenting the declining wild population, and for establishing additional populations within the subspecies' former range. This flock currently numbers 25-30 birds, and includes 7 breeding pairs. Various aspects of the PWRC propagation program have been described by Erickson (1968), Carpenter (1977, 1979), and Derrickson and Carpenter (1981).

In 1979 and 1980, propagation procedures for the Mississippi sandhill cranes at PWRC were modified to avoid hand-rearing. Although eggs were still routinely collected after oviposition to maximize total production, they were placed under Florida, greater, or Mississippi sandhill cranes for incubation. These "foster-parents" were subsequently allowed to complete incubation and raise the young as their own. Human contact was avoided as much as possible during the rearing period.

The full-winged chicks were rendered flightless through the use of vinyl wing brails at approximately 60 days of age. The brails were changed from 1 wing to another at about 14-day intervals to prevent stiffness from developing in the wrist joint. When the colts were about 120 days of age the wing brails were removed and they were transferred to large, covered flight enclosures where they remained until their release. Shelled corn was added to the normal pelleted diet of the cranes selected for translocation in order to precondition these birds to the foods that would be immediately available at the release site. Before shipment the birds were examined, treated with an anthelminthic (Thiabendazole - see Carpenter 1977), and wing-brailed.

The cranes were subsequently transported by air to Mobile, Alabama, and by truck to the MSCNWR release site. The cranes were fitted with leg-band-mounted radio transmitters (Telemetry Systems, Inc., Mequon, Wisconsin, and Telonics, Inc., Mesa, Arizona) and marked for individual identification with color-coded plastic and numbered aluminum leg bands before being released in the holding pen. Their behavior was observed during daylight hours using a spotting scope and binoculars from an elevated blind constructed approximately 200 m west of the enclosure. The approach to the blind was concealed to allow undisturbed access. Data were gathered on daily activity patterns, choice of foods, and associations with released and native cranes.

A small temporary enclosure was constructed in the northwest corner of the pen to facilitate recapture because the cranes had to have their brails removed after the conditioning period. Burlap was attached to the fence of the pen and to the walls of the temporary enclosure to reduce the chances of injury. After the brails were removed and the cranes left the pen, their movements were monitored by radiotelemetric fixes.

RESULTS

Nine parent-reared Mississippi sandhill cranes (8 young of the year, 1 2-year-old) arrived at the holding pen at 1600 hours, 19 January 1981. Transmitters and leg bands were attached to only 4 birds before it became too dark to continue. All birds were released within the pen with plans to recapture and mark the remainder of the cranes the following day. Due to inclement weather on 20 January, the recapture was postponed until 21 January, when the remaining 5 cranes were recaptured, transmittered, marked, and released in the acclimation pen. During recapture, the upper mandible of crane 604 was broken approximately 1.5 cm from the tip. The broken portion of the mandible was removed and the bill cauterized before the bird was marked and released.

Activities of the Cranes While Brailed

During the first 10 days after release, the brailed cranes generally remained in the southeast corner of the acclimation pen. This corner was the farthest from the pen's only entrance--the area where the cranes were marked and released. The vegetation in the southern half of the pen also provided security and escape cover. The birds usually left this corner only when visiting the feeders. During these feeding forays, they remained flocked together. Although 2 feeders were provided, all birds initially fed at the feeder farthest from the entrance gate. The cranes usually went to the feeders 3 or 4 times daily (early in the morning, approximately 0700 hours; midmorning, approximately 1000 hours; mid-afternoon, approximately 1430 hours; and sometimes in the late afternoon, approximately 1700 hours). During this early postrelease period, the birds preferred corn to the pelleted food.

After 10 days, the cranes spent an ever-increasing amount of time foraging while use of the feeders decreased. Cranes then began to utilize more of the acclimation pen and were observed feeding at the 2nd feeder. Late in the 2nd week, the birds began to shift from the feeders to the corn that was scattered on the ground; they also began probing the soil of the prepared crop field near the feeders.

By mid-February, 1 month after their arrival, the brailed cranes fed at the feeders only twice daily, once in the morning and once during mid to late afternoon. While there, most birds probed the loose soil and pecked at the corn scattered on the ground rather than foraging from the feeder. Crane 604, the bird with a portion of its upper mandible missing, continued to use the feeders after all other birds had greatly reduced this activity. The shorter upper mandible appeared to impede this crane's ability to probe or grasp food items on the soil surface.

Activities of Birds After Brail Removal

Brails were removed from selected birds at 1-week intervals over a 3-week period beginning in late February. Brails were 1st removed from cranes 601, 603, and 604. Although capable of flight, these birds remained within the acclimation pen after the brails were removed. Bird 604, however, was observed flying from the pen the following day. This crane remained in the savanna to the south of the pen for the next 2 days and then was again observed in the pen. Cranes 601 and 603 did not leave the pen during the 1st week after brail removal.

When the pen was entered the 2nd week to remove additional brails, all 3 debrailed cranes flew from the pen. Brails were removed from 602, 605, 607, and 609 the 2nd week. As soon as these birds were released, they flew from the pen. During the following week, all birds capable of flight were observed both inside and outside the pen; while outside the pen, however, they remained in the immediate vicinity.

The remaining 606 and 608 were recaptured and debrailed the 3rd week. Brails had not been removed from these birds the 2nd week because their transmitters were inoperable and were to be replaced. These last 2 cranes flew from the pen when released.

Even though the transmittered cranes began to spend less time in the holding pen after all brails were removed, they continued to return daily to feed at the feeders. One feed shed was moved to the crop field outside the pen, and shelled corn was scattered on the ground around this feeder. Although the cranes began to use the feeder outside the pen, they also continued to reenter the acclimation pen to feed.

By early March, the study birds rarely fed at either feeder more than once daily, and then usually only during the mid to late afternoon. During the remainder of March and in April, cranes continued to decrease their use of the provisioned feed. When this report was prepared in June 1981, the cranes were rarely observed in the vicinity of the feeders. However, the shelled corn and prepared pellets were still being provided and will continue to be until crop units are established.

During March, the marked birds shifted their center of activity to a natural savanna approximately 1 km south of the release site. This savanna is bordered by wooded swamps and an open pine upland that was recently burned. Telemetric fixes and observations indicated that the marked cranes were usually located either in the wooded swamp or open pine upland, near the edge of the open savanna. They remained as a flock in this area through June.

Associations Between Native and Released Cranes

The native population of less than 40 (probably 25-30) Mississippi sandhill cranes ranges over more than 300 km^2 of southern Mississippi, reducing the chances for encounters with released cranes. Native cranes were not observed in the vicinity of the acclimation pen until the 3rd week of observation, when a pair of native cranes was observed flying over the pen. The released cranes did not call although they became alert and watched the native cranes.

A pair of native cranes landed in the release enclosure near the feeders 2 days later at approximately 0900 hours and remained until 1400 hours. For the following 2 weeks, this pair returned regularly during mid-morning and remained from 1-4 hours, generally landing near the feeders. While in the pen, the pair was observed feeding on scattered shelled corn and probing in the soil near the feeders. After 2 weeks the pair began to arrive only in the afternoons, but continued to feed in the vicinity of the feeders.

During the initial visits, the native cranes associated with the released birds and established dominance. After about 1 week the native cranes were seldom observed with the released cranes, although occasional encounters occurred when the released cranes were moving to the feeding area. During these encounters the released birds behaved submissively when approached by the native cranes. Since departing the holding pen, the released birds have been observed flying with wild cranes on a number of occasions. However, permanent associations do not appear to have been formed between the native and the captive-reared cranes.

DISCUSSION

As previously mentioned, few attempts have been made to release captive-raised cranes into the wild. However, the experimental releases that were conducted in Florida and Idaho have provided valuable information for designing future releases, and have demonstrated that: (1) compared to parent-reared birds, hand-reared individuals are generally unsuited for release into the wild; (2) compared with older birds, young birds appear better able to make the transition from captivity to the wild and to integrate with wild conspecifics; and (3) captive birds are necessarily unfamiliar with wild conditions (i.e., food items, predators) upon release, and consequently survivorship following release should be enhanced by implementation of "soft" release procedures, such as prerelease conditioning and initial supplemental feeding. All of these findings were incorporated into the release protocol for the Mississippi sandhill crane; each is considered in more detail below.

All 9 captive "parent-reared" Mississippi sandhill cranes translocated to the MSCNWR survived the first 5 months after release. During a similar postrelease period, none of the 17 hand-reared Florida sandhill cranes survived; however, the single parent-reared individual (a female) still survives (Nesbitt 1979, S. Nesbitt, pers. comm.). Similarly, in the Idaho releases 8 of 12 parent-reared greater sandhill cranes survived to make the southward migration (Drewien and Bizeau 1980). Consequently, the success of the Mississippi sandhill crane translocation experiment can be partially attributed to the release of parent-reared captive stock.

Nesbitt (1979) observed that birds reared in captivity by natural parents appeared best suited for release when compared with hand-reared stock. The results of the Idaho and Mississippi experiments support this observation. However, Nesbitt (1979) also stated that cranes less than 1 year old generally proved to be unsuitable for release. The results of the Mississippi release show that parent-reared cranes less than 1 year of age can survive when released into the wild. The Florida sandhill cranes were only 5 months old when released, but the majority of Mississippi sandhill cranes were 8-9 months old at release. This difference may have contributed to the better survival of the birds in Mississippi because they were released at about the age when the normal parent-offspring bonds would be terminated (Walkinshaw 1973, Drewien and Bizeau 1978).

In the Idaho release experiment the 1-year-old individuals seemed much more inclined to associate and integrate with wild conspecifics, whereas the 2- and 3-year-olds tended to remain aloof and associated primarily with each other. It seems highly probable, as suggested by Drewien and Bizeau (1980), that strong ties, which could impede integration with wild conspecifics, do not develop during the 1st year of life. In the Idaho study, integration into the wild flock was considered essential because the released birds had not previously migrated. Eight birds did survive to migrate south but despite intensive searching only a 1-year-old female was relocated on the wintering grounds. Observations during migration and during winter suggested that complete integration with wild conspecifics was achieved by this particular individual.

Finally, the acclimation period at the release site appears to have had a strong role in increasing survivorship. The initial Florida release (Nesbitt 1979) and the initial Grays Lake release (Drewien and Bizeau 1980) were "hard" releases--no special release site conditioning was undertaken. The 2nd Grays Lake release was preceded by food preconditioning at PWRC, and although the birds responded to prepared bait sites immediately following release, there was no release site acclimation period. The 100% survival of the Mississippi birds for the first 5 months compares favorably with the limited success of the aforementioned hard releases.

Because this paper reports on only the first 5-month postrelease period, the overall success of the gentle release technique cannot be thoroughly evaluated. However, based on preliminary results, this methodology should be considered for future releases. Additional releases are now being planned on an annual basis at the MSCNWR, and these will undoubtedly influence future management and conservation efforts for the Mississippi sandhill and other species of endangered cranes.

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MANAGEMENT OF MIGRATORY CRANE HABITAT ON ALAMOSA AND MONTE VISTA NATIONAL WILDLIFE REFUGES

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Abstract: The San Luis Valley, Colorado, has long been a major stopover for migrating greater sandhill cranes (*Grus canadensis tabida*). The Alamosa and Monte Vista National Wildlife Refuges (NWR's) within the valley are major concentration areas for cranes. The refuges and surrounding private land provide roosting, loafing, and feeding habitat for sandhill and whooping cranes (*G. americana*). Cranes are present in the spring from mid-February to early May and in fall from late August to late November. Cranes spend more time in the valley than in their summer or winter ranges. The refuges have over 500,000 crane use days per year. Management practices for cranes consist of flooding meadows and ponds for loafing and roosting habitat, and planting barley, wheat, and field peas for feed. These practices are compatible with waterfowl management. Refuge personnel also provide surveillance during waterfowl hunting seasons, monitor sandhill and whooping crane populations, and provide access for public viewing of these and other bird life. A major management problem is the losses due to collisions with fences and powerlines. Recommendations are made for crane management.

Throughout recorded history the San Luis Valley, Colorado, has been a major stopover point for greater sandhill cranes. Valley residents associate the arrival of spring and fall with sandhill cranes just as some persons associate the arrival of Canada geese (*Branta canadensis*) with these seasons in other parts of the United States. The San Luis Valley is a high mountain valley with elevations varying from 2,280 to 2,380 m. The valley is bordered by the San Juan Mountains to the west and the Sangre de Cristo Mountains on the east. Mountain peaks exceed 4,260 m on both ranges. The climate of the valley is dry and cold with annual precipitation averaging 18 cm/year and temperatures reaching 45°C in winter and 32°C in summer. Despite the arid climate, the valley has abundant groundwater and streamflow from surrounding mountains which produce vast acreages of flooded natural meadows. These are used extensively by cranes as loafing and roosting areas. Abundant grain, principally barley, provides feed for migrating cranes.

Within the valley, the U.S. Fish and Wildlife Service manages Alamosa and Monte Vista NWR's. Alamosa NWR is 6 km south of Alamosa, Colorado, on the east side of the valley. The 4,194-ha refuge consists primarily of natural riverbottom wetland dissected by old oxbows and sloughs of the Rio Grande River. Monte Vista NWR is on the west side of the valley 10 km south of Monte Vista, Colorado. This 5,758-ha refuge consists primarily of flooded meadows, ponds, and some cropland. The refuge has been created by man through extensive dike and pond development. The refuges and surrounding private lands are major concentration areas for cranes. One other crane concentration area, almost wholly in private ownership, exists along the Rio Grande River between Monte Vista and Alamosa.

Since the initiation of the sandhill crane foster-parent program in 1975, whooping cranes have accompanied sandhills to the valley. In an effort to protect the whooping cranes, the U.S. Fish and Wildlife Service in 1978 designated both refuges as critical habitat. As a result of the whooping crane flock and the increase of the greater sandhill crane flock, crane management now receives a higher priority than in the past.

PERIOD OF USE BY CRANES

Since 1975 refuge personnel have recorded whooping crane use of the valley. Whooping cranes generally arrive in mid-February and stay until late April to early May during spring migration. During fall migration they are present from early October to mid-November (Table 1). As the whooping crane population increased from 3 in 1975 to 14 in 1981, the arrival and departure dates have become more similar to the sandhill crane arrival and departure dates.

During the past years, sandhill crane use has generally preceded whooping crane use by 2 weeks to 1 month during the fall and by approximately 2 weeks during the spring. The 1st sandhills usually arrive in late August; they are believed to be a small population (35-50) that nests in northwestern Colorado. After these arrive, sandhill populations gradually increase with peak numbers being reached in mid to late October. By late November nearly all sandhills have left the valley. During spring migration sandhills arrive in large numbers (2,000-5,000) in mid-February with populations reaching their peak in mid to late March. Most sandhills leave the valley from mid-April to mid-May, their departure date depending largely upon spring weather conditions. When the combined spring and fall use is considered, sandhill and whooping cranes spend more time in the San Luis Valley than they do at their nesting or wintering areas.

Sandhill crane use presently exceeds 500,000 use days/year on Monte Vista NWR and 50,000 use days/year on Alamosa NWR (Table 2). A use day is 1 crane using the refuge for any portion of 1 day. Although Table 2 shows an increase in use on both refuges, crane populations have not increased to the extent shown. Use days recorded from 1976 to 1978 are an underestimate because at that time refuge personnel did not survey nighttime roosting populations which considerably exceed daytime use.

Crane use is heavier on Monte Vista NWR in spring than in fall. This difference is a direct result of management. Refuge meadows are flooded to provide loafing areas for cranes and to apply water for waterfowl nesting. Most refuge grain crops are left standing during fall and this standing grain is unattractive to cranes and waterfowl. However, grain crops are mowed during February to provide feed for cranes and waterfowl. Thus, peak populations of sandhills occur during March and April when 8,000 use the refuge.

Table 1. Whooping crane use of the San Luis Valley, 1975-1981.

Year	Date arrived	Date departed
1975	9 Oct	20 Nov
1976	17 Feb	12 May
	5 Oct	17 Nov
1977	21 Feb	8 Apr
	5 Oct	19 Nov
1978	27 Feb	13 Apr
	1 Oct	28 Nov
1979	20 Feb	13 Apr
	29 Sep	16 Nov
1980	8 Feb	10 May
	19 Sep	17 Nov
1981	15 Feb	24 Apr

Table 2. Crane Use Days on Monte Vista and Alamosa NWR's from 1976-1981

	Monte Vista NWR			Alamosa NWR		
Year	Spring	Fall	Total	Spring	Fall	Total
Sandhill cranes						
1976	186,362	94,591	280,953	7,283	16,429	23,712
1977	199,724	181,255	380,979	1,519	7,368	8,887
1978	219,000	155,500	374,500	2,921	19,628	22,549
1979	250,000	138,150	388,150	9,800	31,000	40,800
1980	357,100	152,500	509,600	24,100	29,000	53,100
1981	399,250			60,000		
Whooping cranes						
1975		35	35			
1976	98	7	105			
1977	133	14	147			
1978	80	130	210			
1979	147	70	217	1	64	65
1980	349	101	450	84	35	115
1981	339			30		

The situation is different on Alamosa NWR where meadows and sloughs are flooded during the fall with water diverted from the Rio Grande River. The water is diverted to provide opportunities for hunting and habitat for waterfowl nesting the next spring. There are no pump wells on Alamosa NWR; consequently, the only way to provide sufficient water in spring is to flood during fall and then add water as soon as irrigation ditches flow again in April. Waterfowl and cranes that roost on Alamosa NWR generally feed in barley fields on private land southeast of the refuge. Heavy fall use by cranes and waterfowl, and winter use by waterfowl, leaves these private fields with only small amounts of feed during spring migration. Consequently, in most years, use of Alamosa NWR in spring is not as heavy as in fall. Peak populations have reached 2,500 cranes during fall.

Whooping crane use follows much the same pattern as use by sandhills. On Monte Vista NWR use has increased from 35 use days in 1975 to 450 in 1980 (Table 2). Whooping cranes did not start using the Alamosa NWR until 1979. The major factor behind the increase is the population increase of this species due to the foster-parent program.

HABITAT USED BY CRANES

Habitat used by sandhill and whooping cranes on the refuges is similar. Roosting locations are ponds and sloughs where the birds use water up to 0.3 m deep. Loafing areas are wet meadows of baltic rush (*Juncus balticus*), sedges (*Carex* spp.), spikerush (*Eleocharis* spp.), greasewood (*Sarcobatus vermiculatus*), and a variety of grass species. These meadows do not have to be very wet to attract cranes; 2 to 4 cm of water is satisfactory. Cranes will sometimes use dry meadows as long as a ditch with water or a stream is nearby. Although some feeding activity occurs in meadows, they are primarily used for resting, preening, and other social activities. The other major habitat used is grainfields during morning and evening. Barley is the primary crop so cranes use it most frequently, but will also utilize wheat, field peas, and potato fields. Primary feeding activity in potato fields is searching for insects and grubs. Cranes seem to prefer wheat over barley, and waste grain from wheatfields will be cleaned out rapidly.

Each habitat type is usually used in the course of cranes' daily activities. Cranes leave the roost at or shortly after sunrise and fly to grainfields to feed. Feeding continues until 0930-1000 hours and then cranes fly to loafing areas. At about 1530-1600 hours they fly to grainfields to feed again. About sunset they return to the roost. Weather extremes can cause changes in activity patterns. On extremely cold days cranes will often spend nearly all day feeding in the grainfields. On warm days the amount of time spent feeding will often be 1-2 hours less than normal and more time will be spent at loafing sites.

The distances between roosting, loafing, and feeding areas are important factors influencing crane use. Optimum habitat in the San Luis Valley has all these components within 1-2 km. Cranes fly farther to feed only after grain is completely eaten in nearby fields. Ten kilometers is the maximum distance these cranes have been known to fly from roost to feeding sites.

Although the habitat of surrounding private land is similar to refuge land, different management practices create conditions which influence crane use. Some differences are that most of the meadowland surrounding the refuges is either grazed or hayed, thus privately owned meadows contain closely cropped vegetation. When these meadows are wet they appear to be more attractive than wet meadows on the refuges which contain taller vegetation. Refuge meadows are used less by cranes in fall because we retain the residual cover for duck nesting the next spring. During spring months refuge meadows are flooded earlier than most meadows owned by private landowners and this makes refuge meadows more attractive. During fall, even when many cranes may loaf on surrounding ranches, few of these ranches provide adequate roosting areas like the refuges provide.

CRANE MANAGEMENT PHILOSOPHY AND PRACTICES

Both refuges are waterfowl refuges and many of the management practices designed for waterfowl also aid cranes. On both refuges as much meadow flooding and filling of ponds as practical is conducted. This is done by pumping groundwater from February through May at Monte Vista NWR and by diverting water from the Rio Grande during the fall at Alamosa NWR. Flooding of these meadows provides excellent loafing habitat for cranes and also provides numerous nesting territories for waterfowl. During the fall at Monte Vista NWR some "crane water" usually will be pumped into areas where hunting is prohibited to provide loafing habitat specifically for cranes. Refuge personnel are able to supply roosting habitat by keeping ponds full or nearly full during spring and fall.

At Monte Vista NWR approximately 140 ha (350 acres) of cropland are planted each year to provide feed for waterfowl and cranes. At Alamosa NWR 32 ha (80 acres) are planted. Each refuge has more than double the stated acreage in cropland, but the farm fields are rotated every year because refuge soils are marginal in productivity. Sweet clover, volunteer barley, wild oats, and other plants are allowed to grow in idle fields and then plowed under the next spring to provide some organic matter. Each field is deep chiseled every 3 years to break up the hardpan (crusted soil surface). The chiseled fields provide cranes access to grubs and other insects and cranes use the fields for short periods after chiseling.

If necessary, some of the planted acreage is harvested to provide emergency feed, but most of the crop is left standing in the fall and then mowed during February to provide spring feed. The reason for delaying wildlife use of refuge crops is that most of the private cropland is already harvested when cranes arrive in the fall. There are thousands of acres of stubble fields, surrounding both refuges, where cranes can feed. Feeding activity in these fields causes very little conflict with private landowners. From 1979 to the present, only 1 depredation complaint was received. It is our philosophy that cranes and waterfowl should use private fields and it is not necessary for the refuges to provide their entire feed requirements. Thus, refuge fields are left for spring feed when many of the surrounding private fields have been picked clean by fall crane use and fall and winter waterfowl use. We believe that by providing spring feed the refuges provide critical nutritional needs that are important to crane and waterfowl nesting success during summer months.

During April 1981 refuge personnel surveyed grainfield use on both refuges. Fields at Monte Vista NWR were essentially devoid of grain. Crane populations during the 1st week of April dropped from 6,000 to 300 nearly overnight. These cranes moved north to the Rio Grande River for 7-10 days and then left the valley heading northward. Although spring migration northward was somewhat earlier this year than in some years, I believe that the precipitous decline in refuge populations was probably because there was no feed remaining. Approximately 2,300,000 duck use days, 150,000 goose use days, and 55,000 crane use days had consumed nearly all of 144 ha (359 acres) of 30 bushels/acre barley, some wheat, and field peas. An estimated 10,770 bushels of barley were available during the 1980-81 fall and spring period. Crane feed requirements, an estimated 113 g (1/4 lb) to 151 g (1/3 lb) per day per crane, would consume 25% of the total feed on the refuge with the remainder used by ducks and geese.

In addition to providing the necessary habitat components, refuge personnel also perform other management functions. Weekly counts of sandhill and whooping cranes are conducted on both refuges. Locations and identities of whooping cranes are recorded. During the past 2 years much of the whooping crane watching has been taken over by R. Drewien and his assistants. Refuge personnel do most of the whooper observing before Drewien's personnel reach the valley and after they depart. Several aerial census flights have been flown during spring months in an attempt to count the entire valley population. The San Luis Valley is an excellent spot to monitor the greater sandhill Rocky Mountain flock because nearly the entire population migrates through the valley.

Both sandhill and whooping cranes are present during waterfowl hunting season. Refuge personnel actively patrol during weekends and often during weekdays. The primary focus of law enforcement is to make our presence knwon in order to deter unlawful activities. To date we have had no problems with hunters shooting at or killing sandhill and whooping cranes. Each refuge has 60% of the refuge closed to hunting so birds have a place where they are not harassed. All hunters must park in designated parking areas. During the weekend nearly all hunters are checked as they return to the parking areas. Approximately 50% of all hunters are checked throughout the hunting season. Both refuges receive heavy hunting pressure relative to surrounding areas in the valley. As a result of this pressure, we do not actively try to increase fall crane use on the refuges, and possibly could not even if so desired. At present, waterfowl hunting is not hurting refuge crane populations.

In addition to use by hunters, a 10-km tour route on Monte Vista NWR is provided so that cranes and other birds can be viewed and photographed. Whooping crane tours are given in the spring, and several movies and television programs have been made on the refuges. Public use has been heaviest when cranes have been in the valley, especially since whooping cranes began to use the area.

MANAGEMENT PROBLEMS

Probably the major problem encountered with sandhill and whooping cranes is mortality caused by collisions with powerlines and fences. Drewien (1976) reported that mortality from collisions with aerial obstructions was significant; 2 immature whoopers have collided with fences and 1 with a powerline. All of these accidents have occurred on private land. Sandhill crane deaths from similar accidents have occurred on the refuges. Although there are no data on sandhill mortality, it is fairly common to see dead sandhills under powerlines near grainfields. Most mortality seems to occur during foggy mornings or in periods of high wind when birds are flying from roosting areas to grainfields or vice versa. The cost of burying powerlines is prohibitive. Fences cannot be removed because they are a necessary part of our grazing program, which is our major grassland management tool. All unneeded fences have been removed. Even if all fences and powerlines on the refuges were removed, it would only be a small portion of the hazards cranes face.

The only other problem which may become more acute in the future is the cropland management program on the refuges. With the increase of the crane population, the cranes are beginning to take a significant portion of our feed. In the future, due to budget cuts, we may not be able to adequately feed both cranes and waterfowl.

CONCLUSIONS AND RECOMMENDATIONS

Based on our experience, the following recommendations are made for other areas that may be or will become involved in crane management.

1. Waterfowl and crane management appear to be compatible. Good nesting habitat for waterfowl is also good crane loafing habitat. Management practices such as flooding meadows in the fall, which do not specifically help waterfowl, can be used to entice cranes into a certain area.
2. Grainfields, roosting areas, and loafing areas should be within 4-5 km of each other and closer if possible. Optimum habitat in the San Luis Valley has these features within 1-2 km of each other.
3. Grain should be available in a condition attractive to cranes when they need it most. Any cropland management program should consider surrounding cropland practices such as harvest time, fall plowing, and other aspects which will influence grain availability, crane distribution, depredation complaints, and other factors. The less grain available on surrounding private land, the greater the responsibility of the refuge manager to provide such food.
4. Powerlines, telephone lines, fences, or other aerial obstructions should be kept to a minimum. If possible, do not allow new lines to cross areas which receive heavy crane and waterfowl use. Although the refuges will continue to try to keep mortality to a minimum, it is our philosophy that some mortality from these and other factors is inevitable. Both sandhill and whooping cranes have to survive in a modern world. It is impossible for management to remove all hazards.

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FACTORS AFFECTING TRAP-RELATED MORTALITY OF SANDHILL CRANES[1]

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Abstract: A total of 1,456 sandhill cranes (*Grus canadensis*) was captured with rocket nets near Rich and Mound Lakes, Terry County, Texas, in January and February 1979 and 1980. Nearly 5% of captured cranes was incapacitated during and immediately following net extension. An additional 10% was processed, released, and later found dead near the trap site. The age and sex composition of cranes released and later found dead did not differ ($P = 0.53$) from cranes that survived. The proportion of cranes that was released and later found dead varied between trapping attempts ($P = 0.006$) but did not vary between trapping locations ($P = 0.95$) or between cranes marked with radio transmitters and cranes marked with neck collars ($P = 0.56$). Mortality related to trapping was not associated ($P > 0.05$) with numbers of cranes captured, hour of day, temperature, wind speed, or a stress variable. Mortality varied with wind chill ($P = 0.02$) but the relationship was unclear. The percentage death rate was the same ($P = 0.66$) for cranes released in dry, wet, or muddy conditions. Time spent under nets before processing did not affect survival of sandhill cranes ($P > 0.70$).

Sandhill cranes are difficult and expensive to capture in large numbers. Ramakka (1979) noted 10-14% losses while capturing sandhill cranes with rocket nets in Texas. Wheeler and Lewis (1972) and Ramakka (1979) suggested that trap-related mortality of sandhill cranes could be reduced by elevating rockets to 45° and by processing and releasing cranes quickly after capture. We tested the relationship between trap-related mortality of cranes captured with rocket nets, and selected variables that might be controlled by trapping crews.

We thank G. C. Iversen for field assistance and valuable comments throughout this study.

METHODS

In January and February 1979, 740 cranes were captured at Rich and Mound Lakes, Terry County, Texas. A total of 715 cranes was trapped during the same period in 1980 at Rich Lake. Six rocket nets, using 4 rockets per net, were fired over cranes attempting to drink at freshwater springs (Ramakka 1979). All cranes were marked with a U.S. Fish and Wildlife Service (FWS) aluminum legband and a plastic neck collar. Cranes captured in 1979 were also marked with colored legbands, and 21 cranes (9 in 1979 and 12 in 1980) were fitted with a backpack radio transmitter. Each crane was released immediately after handling onto the lake bed that served as a roost for 30,000-120,000 cranes.

Trap-related deaths were divided into immediate or delayed categories for analysis. Nearly 5% of captured cranes was immediately incapacitated (could not walk or fly from the trapping site) during net extension (Table 1). In 1980, all incapacitated cranes, and 42 additional cranes were sacrificed for later laboratory analysis. An additional 10% of captured cranes that was marked and released was later found dead during extensive inspections of the lake bed near the trap site. For purposes of statistical analysis, marked cranes that we found dead were assumed to represent a random sample of all marked cranes that died within a week of capture and release. Statistical analyses were performed using the Statistical Analysis System (Barr et al. 1979).

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Table 1. Fates of sandhill cranes captured at Rich and Mound Lakes, Terry County, Texas, in 1979 and 1980.

Status	1979 No.	1979 %	1980 No.	1980 %	Total No.	Total %
Alive	658	86.2	602	84.1	1,240	85.2
Immediately incapacitated	40	5.4	32	4.5	72	4.9
Released - found dead	62	8.4	82	11.4	144	9.9
Total	740	100.0	716	100.0	1,456	100.0

After nets were fired and secured over captured cranes, individual cranes were marked and released at the rate of 1 every 90 sec. The date, time, location, band numbers, marker type (radio or just neck collar and legbands), extent of dry, wet, or muddy feathers, weight and 3 morphometric measurements, and age of each crane were recorded. Juveniles were identified by brown feathers on the nape (Lewis 1979). Sex of all dead cranes was determined by gonadal examination. Weather data were obtained from the Lubbock Station (within 48 km of trap sites) of the U.S. Weather Service. Temperature and wind speed were recorded at the time of banding each captured crane.

RESULTS AND DISCUSSION

Initial Incapacitating Injuries

Cranes fatally injured during net extension had, in descending frequency of occurrence, broken legs, wings, and vertebrae, or were otherwise unable to walk or fly from the trapping site. There was no difference in the proportion of cranes initially fatally injured at either lake where cranes were trapped in 1979 (X^2 = 0.48, df = 1, P = 0.40). The sex ratio of initially fatally injured cranes was not different from 50:50 (X^2 = 1.44, df = 1, P = 0.23), and the age ratio was not different (X^2 = 1.73, df = 1, P = 0.21) from the 10% juveniles estimated from field age ratios (Unpubl. data, Okalhoma Coop. Wildl. Res. Unit.)

Analysis of high-speed 8-mm motion pictures taken during this study revealed that all cranes at the trap site were airborne before nets were fully extended, regardless of their behavior before firing of the rockets. Only a small proportion of initially fatally injured cranes were struck with rockets or the leading edge of the nets. Cranes appeared to be injured most commonly as a result of being flighted when nets overtook them and brought them sharply to the ground. Rockets (and ultimately extended nets) angled above 45° resulted in most of the cranes escaping capture by outflying nets. Rockets angled less than 45° tended to decapitate cranes nearest the nets, thus slowing net extension and allowing other cranes to escape capture. Use of 4 rockets per net rather than 3 increased the speed of net extension and reduced the percentage of escaping cranes. A 45° angle minimized escape of cranes and reduced deaths from impact with rockets or the leading edge of the net.

Cranes Released and Later Found Dead

There was a significant difference between trapping dates in the proportion of cranes released and later found dead (Table 2). The sandhill crane hunting season was in progress in January in Texas during both years of this study. Examination of cells in X^2 analysis indicated no relationships between trap-related deaths and the months of January and February. Differences in death rates between trapping attempts were not related to trapping during the sandhill crane hunting season.

The proportion of sandhill cranes marked, released, and later found dead did not differ between trap sites at Rich and Mound Lakes (Table 3) despite muddier conditions at the Mound Lake trapping site. The use of radio transmitters did not result in death rates higher than those of cranes marked only with neck collars, and age and sex classes were equally vulnerable to trap-related mortality.

The hour of day during which cranes were captured was not associated with the proportion of cranes released and later found dead (Table 4). Wind speed was not associated with death rates, but

Table 2. Distribution by date of sandhill cranes marked, released, and later found dead at Rich and Mound Lakes, Terry County, Texas, in 1979 and 1980.

1979			1980		
Julian date	Assumed alive	Found dead	Julian date	Assumed alive	Found dead
14	22	2	1	13	1
15	7	0	5	33	3
17	22	4	7	118	17
19	50	4	14	44	2
22	72	15	36	26	1
23	25	4	37	77	13
24	66	4	38	49	9
27	4	1	50	20	9
32	1	1	53	49	4
33	3	0	54	66	6
38	63	5	57	23	6
39	60	7	58	83	12
40	132	5			
42	111	10			

$\chi^2 = 21.80$, df = 13, $P = 0.06$ $\chi^2 = 19.82$, df = 11, $P = 0.05$

Combined years: $\chi^2 = 44.85$, df = 24, $P = 0.006$.

Table 3. Distribution by lake, marker type, age, and sex of sandhill cranes marked, released, and later found dead at Rich and Mound Lakes, Terry County, Texas, in 1979 and 1980.

Variable	Assumed alive	Found dead	χ^2	P
Lake (1979 only)				
Rich	573	52	0.01	0.95
Mound	101	10		
Marker type (1979 and 1980)				
Radio	18	3	0.37	0.56
Neck collar	1,231	141		
Age (1979 and 1980)				
Adult	1,099	124	0.39	0.53
Juvenile	151	20		
Sex (1979 and 1980)				
Male	31.5[a]	33	0.07	0.80
Female	31.5	30		

[a] Expected values assuming a 50:50 sex ratio in population.

Table 4. Associations of environmental variables with sandhill cranes marked, released, and later found dead at Rich and Mound Lakes, Terry County, Texas, in 1979 and 1980 (years combined).

Variable	χ^2	df	P
Hour of day	14.22	10	0.16
Temperature	38.76	27	0.07
Wind speed	15.78	17	0.54
Wind chill	48.16	28	0.01
Stress[a]	67.31	52	0.08

[a] Calculated as stress = wind chill - (3 X wind chill X wetdry/4) where wetdry = 1 if crane was wet or 0 if crane was dry.

Table 6. Comparison of sandhill cranes released in dry, wet, or muddy condition in Texas (assumed alive) and cranes later observed to be flighted (data from 1980).

	Condition at time of release			
Status[a]	Dry	Wet	Muddy	Total
Assumed alive	377 (63%)	117 (19%)	107 (18%)	601 (100%)
Observed alive	109 (62%)	36 (20%)	32 (18%)	177 (100%)

[a] $\chi^2 = 0.089$, df = 2, $P = 0.96$ for H_0: no difference between cranes assumed and observed alive.

the rate of death was associated with the temperature, wind chill, and stress. The highest death rates appeared to be associated with the mid-ranges of temperatures, wind chill, and stress. Extremes of these 3 variables did not appear strongly associated with death rates. We believe that confounding of date with temperature, wind chill, and stress was responsible for the observed significant associations, despite pooling data from both years of analyses.

Results of factorial analysis of variance indicated that being wet or muddy, and processing time, were unrelated to death rates (Table 5). Chi square analysis verified no difference in death rates among cranes released in a dry, wet, or muddy condition. Cranes released in dry, wet, or muddy condition (assumed alive) were later observed to be flighted (observed alive) in equal proportions (Table 6). Processing time was directly related to the number of cranes captured, and there was no association between numbers of cranes captured and the percentage of cranes released and later found dead in 1979 ($r = -0.306$, df = 12, $P > 0.25$) or 1980 ($r = -0.015$, df = 10, $P > 0.80$).

CONCLUSIONS AND RECOMMENDATIONS

A program of banding 4,000 sandhill cranes per year in western Texas for 5 years is needed to accurately assess survival rates of this population. About 4-7% of cranes captured with rocket

Table 5. Effects of being wet and processing time on sandhill cranes marked and released on Rich Lake, Terry County, Texas, in 1980.

Dry, wet, or muddy	Status	N[a]	Mean processing time time (hours)[b]	SE
Dry	Alive	377	0.63	0.027
Dry	Dead	52	0.63	0.078
Wet	Alive	117	0.67	0.047
Wet	Dead	13	0.78	0.178
Muddy	Alive	107	0.60	0.040
Muddy	Dead	17	0.49	0.094

[a] $\chi^2 = 0.84$, df = 2, $P = 0.66$ for H_0: No difference in proportion of cranes dying after being banded dry, wet, or muddy.

[b] 2-way ANOVA: F = 0.48, $P = 0.70$.

nets can be expected to be initially incapacitated during net extension. An additional 5-10% of cranes released after banding in Texas can be expected to die. We recommend searching both the lake bed and surrounding upland areas for dead cranes when trapping near salt lakes in Texas. None of the potentially controllable variables tested in this study could be associated with increased death rates, and we were unable to delineate alternatives that will reduce current mortality rates.

Our experience indicates that large numbers of sandhill cranes can be captured and marked without distorting age or sex ratios of the population. Banding wet or muddy cranes, processing of cranes for long periods or banding large numbers of cranes at 1 time, banding during the hunting season, or marking with radio transmitters could not be associated with mortality expected when rocket netting sandhill cranes. However, we do not recommend banding at extremely wet or muddy trapping sites. Wet and muddy conditions at trapping sites can be improved by channelizing shallow water areas to drain them. Despite the lack of clear associations between trapping mortality and weather variables, we do not recommend banding during cold (<-5°C) or windy (>40 km/hr) weather. Birds fatally injured during net extension can be used to monitor annual or seasonal changes in body condition, parasite or disease prevalence, or other physiological parameters.

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A FUNDING SOURCE FOR SANDHILL CRANE RESEARCH: THE ACCELERATED RESEARCH PROGRAM FOR MIGRATORY SHORE AND UPLAND GAME BIRDS

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Sandhill cranes (*Grus canadensis*) in North America are a major migratory bird resource. Both state and federal research emphasis on cranes began to increase in 1967 when the Accelerated Research Program (ARP) for Migratory Shore and Upland Game Birds was implemented. Additional emphasis occurred with the transfer of sandhill cranes to game bird status in increasing numbers of western states and when the U.S. Fish and Wildlife Service started the sandhill crane foster-parent program for the endangered whooping crane.

The ARP is a cooperative state-federal program that provides a mechanism for increasing research efforts not only with sandhill cranes but also with snipe (*Capella gallinago*), rails (*Rallus* spp., *Porzana* spp.), purple gallinule (*Porphyrula martinica*), common gallinule (*Gallinula chloropus*), morning dove (*Zenaida macroura*), white-winged dove (*Zenaida asiatica*), woodcock (*Philohela minor*), coot (*Fulica americana*), and band-tailed pigeon (*Columba fasciata*). ARP funds may also be used for studies on nongame shorebirds, but funds may not be used for endangered species research. The ARP has funded 113 projects in 41 states totaling $2.4 million through 1980-81.

A 14-member national committee sets program policy and recommends approval or rejection of proposals submitted each year. The chairman of this committee is a member of the Migratory Wildlife Committee of the International Association of Fish and Wildlife Agencies.

To obtain funds, proposals are prepared and submitted by the originating organization. They are evaluated and ranked in priority by region. If the proposal is submitted by other than a state Fish and Wildlife Agency (e.g., a university), it must receive signed approval by that state's Fish and Wildlife Agency. Proposals are then forwarded to the Technical Committee Chairman for ARP, in the region where the work is to be done. The regional chairmen are:

West :	Mr. Harold Harper, California Fish and Game
Central :	Mr. Ronnie George, Texas Parks and Wildlife Mr. Jerry Horak, Kansas Fish and Game
Midwest :	Dr. James March, Wisconsin Department of Natural Resources
Northeast:	Mr. Charles Allin, Rhode Island Division of Fish and Wildlife
Southeast:	Mr. Larry Soileau, Louisiana Wildlife and Fisheries Commission.

Proposals should be submitted by 1 October each year to be eligible for the following year's funds. Annual funding is $175,000 for contract research, pending Congressional appropriation. Of this, about 33% or $60,000 is available for funding new proposals; the remaining is used to continue ongoing studies.

The mission of ARP is to gain a better understanding of this group of migratory birds in order to keep pace with the demands placed on them from a variety of sources. The Program is not only a mechanism for research funding but for publishing and distributing results of the studies. An annual report lists recently completed studies and active projects being funded. ARP funds were also used in 1977 to publish a book entitled *Management of Migratory Shore and Upland Game Birds in North America*. Over 9,000 copies have been distributed or sold. The book was reprinted in 1980 and is available from the University of Nebraska Press.

The 1st sandhill crane study funded through ARP was in New Mexico in 1972. Since then, 5 additional studies have been funded: 2 in Oklahoma, and 1 each in Arizona, Indiana, and Alaska. One of the Oklahoma studies has been completed (Factors Affecting the Platte River Crane Census), carried out through the Oklahoma Cooperative Wildlife Research Unit. The remaining 4 are ongoing. The total amount expended on sandhill cranes through ARP is $208,800 through 1980-81, or $14,900 per year. However, in the last 5 years $37,661 has been expended each year. The average cost per crane project is $34,800. Project duration averages 3.3 years.

Ongoing ARP-funded crane research is under way in 4 states (Table 1). The Alaska crane research centers around the important Copper River Delta staging area. Objectives of this work are to determine numbers and distribution, estimate productivity, and evaluate the impact of harassment, from aircraft and boat traffic on these staging birds. Indiana crane research also deals with a staging area, the Jasper-Pulaski Fish and Wildlife Area, used by the eastern component of the greater sandhill crane (*Grus canadensis tabida*) population. Objectives of this study are to enum-

Table 1. Past and ongoing crane research funded through the Accelerated Research Program for Migratory Shore and Upland Game Birds.

State	Project costs	Principal investigators	Duration
New Mexico	$ 3,200	James L. Sands	1974-76
Oklahoma	4,480	James C. Lewis	1975-77
Arizona	25,600	David E. Brown	1978-81
Indiana	24,358	James R. Lovvorn	1978-81
Alaska	42,923	Peter G. Mickelson	1978-81
Oklahoma	118,257	James C. Lewis	1976-77
		Paul A. Vohs, Jr.	1977-81

erate total numbers of cranes using the area and to determine if there is a potential for the large numbers of cranes to damage the carrying capacity of the Jasper-Pulaski habitat. Arizona crane research is examining aspects of crane wintering ecology on the Willcox Wildlife Management Area in southeastern Arizona. Since 1960, crane numbers at Wilcox have risen from less than 100 to several thousands, and sound management plans are needed to allow for expanding populations of cranes wintering in the Southwest. Finally, the staff of Oklahoma Cooperative Wildlife Research Unit is also studying crane wintering grounds to determine age at 1st breeding, to study pairing behavior, and to determine migration routes and breeding areas through observing marked cranes.

General categories of research needs for sandhill cranes are information on breeding biology and behavior, crane taxonomy including age and sex determination studies, habitat requirements including tolerance of disturbance as well as habitat inventories, productivity estimates, food habits including crop depredations, and what type of use the public would like to make of the crane resource.

SIBERIAN CRANES FOR NORTH AMERICA

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Abstract: The population of Siberian Cranes (*Bugeranus* [*Grus*] *leucogeranus*) has declined to perhaps 150 birds. The demographic problem of the species in its native continent, Asia, is attributed to hunting during migration and encroachment by humans into wintering habitats. Although conservation efforts are under way in China, India, Iran, and the USSR, the bleak reality of human needs may cause the demise of these wild cranes in the near future. The eastern population of Siberian cranes winters in China and nests sympatrically with lesser sandhill cranes (*Grus canadensis canadensis*) in the USSR. If numbers of Siberian cranes continue to decline, these lesser sandhills could easily be used as foster-parents for Siberian crane eggs. Such a foster-parent program could establish a secure Siberian crane population that would winter in the United States and Mexico, but breed in traditional nesting habitats in the USSR. Problems considered in this proposal include (1) habitat accommodations for Siberian cranes, (2) the potential interactions between Siberian cranes and the externally similar whooping cranes (*Grus americana*), (3) the effect of sandhill crane hunting on Siberian cranes and international politics, and (4) the opinions against species introduction. However, the proposal offers another option for the survival of Siberian cranes, as well as opportunities for expanded cooperation between Asian and North American nations.

STATUS OF SIBERIAN CRANES

The traditional flock of whooping cranes has slowly made a comeback from a low of 18 birds in 1938 to about 80 in 1981. This achievement can be credited to decades of cooperation between the governments of Canada and the United States, and the activities of private organizations such as the Saskatchewan Museum of Natural History, the Whooping Crane Conservation Association, Incorporated, and the National Audubon Society. The large white crane of Asia, the Siberian crane, has likewise declined from many thousands in the early part of this century to as few as 150 birds in the 1980-81 winter counts (J. Delacour, 1980 pers. comm.). But unlike the whoopers whose numbers are now increasing due to international cooperation, the Siberian crane population continues to decline. Since 1973 the International Crane Foundation (ICF) has made efforts to understand the biological requirements of Siberian cranes, to identify limiting factors, and to develop conservation programs with and among Afghanistan, China, India, Iran, and the Soviet Union.

The Siberian cranes breed on the arctic tundra of the USSR in 2 widely separated groups: the eastern flock nests between the Lena and Indirka Rivers, while the western population frequents wetlands near the mouth of the Ob River. In recent years Dr. Vladimir Flint, and colleagues from the Soviet Institute for Nature Conservation in Moscow, have monitored the eastern flock, which contains most of the birds; the productivity of this flock depends on the weather. As many as 40 widely scattered nests can be found during warm springs while as few as 6 nestings occur during cold springs. Extrapolating from transect surveys across the great expanses of tundra, the Soviets also calculated that perhaps as many as 200 birds constitute the eastern population, although fewer than 100 birds were actually confirmed (Flint 1978).

A tally of the Siberian crane population is most easily taken on the wintering grounds where the birds flock and occupy a fraction of the space used during the breeding season. The eastern population of Siberians could therefore best be evaluated by counting the cranes on their wintering grounds along the Yangtze River in China. Dr. Chou Fu-Chang of the Beijing Institute of Zoology searched for the wintering cranes from 1978-81. It was not until February of 1981, however, that he found a relict flock of 100 birds wintering in a swampy area along the mid-regions of the Yangtze River in the northern part of Jiangxe Province. His count matched the Soviet confirmed counts on the tundra suggesting that, unless Siberian cranes winter elsewhere in China, the eastern population numbers half the Soviet extrapolated estimate of 200 birds.

Dr. Chou defined the winter habitat of Siberian cranes in China as an expanse of shallow, freshwater marshland similar in gross features to wintering grounds of Siberian cranes in India and Iran (Sauey 1976, 1978a). In west Asia the Siberian cranes are specialized aquatic vegetarians feeding on the submerged tubers of sedges. The Siberian cranes in China were in company with white-naped cranes (*Grus vipio*), a species that feeds on sedge tubers in marshlands on their wintering grounds in the Republic of Korea. Probably the Siberian cranes in China are also specialized aquatic vegetarians depending on the natural integrity of acreages of shallow water that support a large biomass of sedge tubers. The survival of Siberian cranes in China, therefore, is based on conservation of riparian wetlands near the Yangtze and, of course, protection of cranes from dis-

disturbance--particularly hunting.

Based on Dr. Chou's findings, China's foremost ornithologist Dr. Tso-hsin Cheng (also at the Beijing Institute of Zoology) advised the Ministry of Forestry that the wetlands used by Siberian cranes should be protected as a Nature Reserve, similar to sanctuaries established in northeastern China for the endangered red-crowned crane (*Grus japonensis*) and on the Tibetan Plateau for the little-known black-necked crane (*Grus nigricollis*). Concurrently, developers in China are constructing a series of hydropower dams across the Yangtze River. I do not know if the winter area of the Siberian cranes is within planned flood pools of the dams. The subadult Siberian cranes that accidentally migrated to Japan (where most natural wetlands have been converted to agriculture) would have perished from starvation had they not been captured while in a weakened condition and revived at zoos (Kawata 1974). This failure of subadult cranes to adapt to upland feeding provides evidence that the conservation of natural wetlands in China is vital to the survival of Siberian cranes.

Little is known about the Siberian cranes on their 9,650-km migration between the tundra and the Yangtze. The cranes are strictly protected by legislation in China, Mongolia, and the USSR, but conservation laws are often unknown and poorly enforced in back areas. Dr. Flint and his colleagues continue their efforts to designate the breeding grounds of the eastern Siberians as a Nature Reserve to preclude the summer grazing of domestic herds of reindeer in the region. The reindeer population is increasing and the herds may disturb the nesting cranes, or even trample their eggs (Flint and Kistchinski 1981).

The western flock is in even greater peril than the eastern Siberians. Their breeding grounds were not known until a lone prefledged chick was captured there in 1978. The chick was found along a tributary of the lower reaches of the Ob River near the base of the Yamal Peninsula, which juts out into the Kara Sea. In 1981, Dr. Sasha Sorokin, of the Flint team, conducted an aerial survey of the area and located 8 Siberian crane nests near the Kunevat River, a tributary of the Ob; a region that in the near future may be protected as a nature reserve. There may be 2 separate nesting groups in west Siberia, because the western population of cranes winters in 2 locations. One flock winters in northeastern Iran with a migration route through the Astrahan Nature Reserve on the Volga River delta, at the northeast corner of the Caspian Sea. A 2nd flock migrates south near the Aral Sea, then across the Hindu Kush Mountains of Afghanistan, to wintering grounds on the Gangetic Plain of northern India.

Dr. V. Y. Vinogradov, of the USSR Bird Banding Center, has observed, during crane migration periods, several Siberian cranes resting on wetlands of the Astrahan Nature Reserve. These cranes are believed to be those that winter on wetlands near the town of Feredunkenar on the southeast Caspian lowlands of Iran because the spring arrival dates of Siberian cranes at the Astrahan Nature Reserve do not match with the migration dates of Siberian cranes that winter in India.

Until 1978, Siberian cranes were believed extirpated by hunters from their historic winter range along the Caspian. Ironically, the surviving flock was discovered by ornithologist Mr. Mohammed Ali Ashtiani in a waterfowl hunting area, where wild ducks are lured into small ponds to be netted and clubbed (Sauey 1978a). Ducks are baited to and are not disturbed at a large flooded field near the small ponds. Ironically, in February 1978, 12 Siberian cranes were discovered wintering on the large flooded and undisturbed fields, accidentally protected because the duck hunters did not want to flush the large flocks of ducks, some of which might be lured to the small ponds. In 1981, biologists Mr. Mohammed Reza Vazarie and Mr. Heidar Fharatpur of the Iran Department of the Environment, reported 16 Siberian cranes wintering in Iran--an encouraging increase. The cranes are protected as long as they remain on wetlands adjacent to the trapping ponds; however, our Iranian colleagues report that hunting is widespread in other areas and that cranes could easily be shot.

Likewise, the flock that winters in India is hunted during migration through the passes of the Hindu Kush Mountains of Afghanistan and Pakistan. Thousands of common (*Grus grus*) and demoiselle cranes (*Anthropoides virgo*) also migrate through the same regions as the Siberians and provide food and sale items for local people doing subsistance and commercial hunting each spring and autumn. The cranes are baited within range by living and stuffed decoy cranes, then shot. In fact, our 1st clue that Siberian cranes migrated through Afghanistan was a report that white cranes were for sale in a Kabul meat market.

Lake Ab-i-Estada, Afghanistan, is a regular resting area for migrating Siberian cranes. In late March 1977, Ronald Sauey of ICF identified 56 Siberians at Lake Ab-i-Estada as the individuals he studied that winter at the Keoladeo Ghana Sanctuary (KGS) near Bharatpur, India (Sauey 1977a). The current political climate in Afghanistan, particularly in the back areas, is not conducive to any type of conservation effort, and the hunting pressures are quite likely to increase.

The Siberian crane is best known on its wintering grounds in India. Not only are the birds protected and thus easily approached, photographed, and studied, but they inhabit 1 of the world's greatest water bird sanctuaries, the KGS. This refuge attracts thousands of visitors annually to view, at close range, the great diversity and number of both resident and migratory birds.

ICF's Ronald Sauey has comprehensively examined the biology of Siberian cranes at KGS since 1974. Much of our understanding of the ethology and winter ecology of the cranes derives from Sauey's studies and those of his colleague Paul Spitzer (Sauey 1978b, Spitzer 1978). They determined that the Siberian crane feeds almost exclusively on the tubers of sedges (*Cyperus rotundus* and *Eleocharis* sp.). *C. rotundus* is also a common weed in agricultural fields in northern India. Although there is an apparent abundance of the Siberian cranes' preferred food, the sedges must be covered by shallow water before the cranes will excavate and consume them. Unlike the large and successful Indian sarus crane (*Grus antigone antigone*) that excavates sedge tubers from dry ground, the Siberian crane is a more specialized feeder and is never observed outside wetland habitats in winter. The natural drying of India's wetlands in winter, concomitant with the advance of the arid season and coupled with the drainage of marshlands for agriculture, limits available habitats for Siberian cranes. The threat is, of course, less critical than the hunting pressures in Afghanistan and Pakistan.

CONSERVATION PROGRAMS

The security of the KGS was additionally solidified by the recent transfer of its administration from state to federal authorities. The Indian Ministry of Agriculture is building a hydrobiological research station near KGS in cooperation with the United States Department of the Interior. Indira Ghandi is personally interested in wildlife conservation and, at a reception in conjunction with the 1981 meeting of the Convention on International Trade in Endangered Species (CITES), American wildlife artist, Diane Pierce, presented to the Prime Minister an original oil painting of Siberian cranes at KGS. Posters will be made from the painting to promote wildlife conservation throughout India. India's Hindu culture, coupled with conservation interest at top administrative levels, makes the subcontinent a fertile habitat for wintering Siberian cranes--if problems the birds face during migration can be circumvented.

Conservationists in China, India, Iran, and the USSR are ardently striving to save the Siberian cranes. They are to be congratulated on their noteworthy achievements in recent years. Since 1976, cooperative efforts have been undertaken, through the auspices of the US-USSR Environment Agreement of 1972, to establish Siberian cranes in captivity at ICF (USA), at the Oka State Nature Reserve (OSNR) in the Soviet Union, and Vogelpark Walsrode in West Germany (Archibald 1980). The propagation program was modeled after the work of the Patuxent Wildlife Research Center in their successful efforts to propagate whooping cranes in captivity and to restock rare cranes back into the wild.

Through the cooperation of the Vogelpark Walsrode (West Germany) and Hirakawa Zoo (Japan), 3 adult Siberian cranes were imported to ICF. Twenty-three young Siberian cranes also have been established at 4 centers (ICF-6, OSNR-13, Vogelpark Walsrode-3, Tama Zoo-1), primarily by collecting hatching eggs from the eastern population of wild Siberian cranes (Sauey 1977b). Siberian cranes usually lay a 2-egg clutch, but have never been reported to rear both chicks. Half the eggs are therefore assumed available for collecting.

In 1981 a chick was hatched and is now being reared from an adult pair of Siberians at ICF. This landmark event is the 1st rearing of a Siberian crane in captivity from an egg laid in captivity. Most of the captive cranes are subadults. As they reach sexual maturity the captive population is expected to grow rapidly, thus providing new options for Siberian crane management.

Unlike the wild Siberian, which nests in early June during the late arctic spring, captive Siberians held at mid-latitudes nest from late March through mid-May. This season overlaps the nesting period of the common cranes at mid-latitudes in Asia. The common crane is an abundant bird breeding through much of the boreal zone from northern Europe to eastern China and wintering from northwest Africa to Japan. Populations of common cranes that both breed and winter in protected areas, and that are not hunted during migration, could be selected as foster-parents for Siberian crane eggs produced in captivity.

To initiate this undertaking, ICF and the Iran Department of the Environment began research in 1975 on common cranes wintering in Arjan National Park in southwest Iran. The park contains excellent potential for Siberian crane wetland habitats and large numbers of common cranes. More than 200 common cranes were color-marked and their breeding grounds were determined to lie between Moscow and the Ural Mountains and in nearby OSNR. OSNR supports a flock of captive Siberian cranes as well as more than 50 nesting pairs of wild common cranes. When the captive Siberian cranes produce fertile eggs, the eggs can be substituted into the nearby nests of common cranes to start a new flock of wild Siberian cranes in west Asia that presumably would winter within the Arjan National Park, Iran. Recent political developments in Iran have complicated the above program. However, ICF has resumed communication with Iranian crane researchers and perhaps cooperative programs will resume in the near future.

In India, ornithologist Prakash Gole is organizing a Crane Study Group to determine, among other things, the Indian wintering habitats of common cranes that migrate through unhunted passes of the Himalaya Mountains in Kashmir and Nepal. Color-marking of these cranes during their migration will allow identification of the populations on both wintering and breeding grounds and thus an opportunity to initiate a new and more secure Siberian crane flock via the cross-foster technique, a flock that winters in India yet avoids the treacherous passage over Afghanistan and Pakistan.

Despite the optimistic plans for the future of Siberian cranes in Asia, the stark realities of the 1980's loom on the horizon. The complexities of cooperative efforts among politically polarized nations, the pressure from hunting, the acute human population pressures in southern Asia, and the associated drive to drain wetlands for agriculture, darken the horizon for the 150 cranes.

The sandhill cranes that nest in eastern Siberia and winter in North America, provide an innovative possibility in Siberian crane conservation.

METHODS

Since 1975 Canadian and U.S. biologists have endeavored to establish a 2nd population of migratory whooping cranes by substituting whooping crane eggs into the nests of sandhill cranes at Grays Lake National Wildlife Refuge, Idaho. The whoopers successfully hatch, fledge, and migrate south with their sandhill foster-parents.

Particularly during migration and winter months sandhills are largely vegetarian, feeding in dry agricultural fields, unlike the whooping cranes. Although whooping cranes occasionally feed in upland dry areas, they prefer shallow wetlands where they are predominantly carnivorous. Surprisingly, the sandhill-reared whooping cranes have "shifted" feeding habitats completely and have successfully learned to feed in the sandhills' upland feeding niche. After the immatures become independent of their foster-parents they continue to follow the migration path of the Grays Lake sandhills, demonstrating that migration is learned in whoopers, and probably also in other crane species. After reaching sexual maturity several males have now returned to Grays Lake to establish breeding territories. Unfortunately, in 1980 and 1981 the territorial birds were all males, and females of breeding age were not available. This problem may be circumvented as young females reach reproductive maturity, and as captive-reared females are paired to and released with the territorial males. Biologists believe that sandhill-reared whoopers are not sexually imprinted on sandhills, that they recognize and are attracted to whoopers, and that they may be breeding in the near future.

A similar methodology could be applied to Siberian cranes and lesser sandhills in eastern Siberia. More than 30,000 lesser sandhills breed in eastern Siberia. They range from the Bering Sea as far south and including the Kamchatka Peninsula, and west to the Indigirka River lowlands where their distribution overlaps that of the eastern population of Siberian cranes. Unlike the Siberians that winter in southern Asia, the sandhills migrate east across the Bering Sea to Alaska, then south through central Canada and the Great Plains of the United States to winter primarily in west Texas, northern Mexico, and the Central Valley of California (Boise 1978).

Siberians and sandhills nest simultaneously and in sympatry in northeast Asia, thus making it possible to easily remove 1 Siberian crane egg from each nest containing 2 eggs and to substitute the lifted egg into a sandhill nest, after having removed the sandhill eggs. The Siberian crane would be reared by the sandhills among or near Siberian crane pairs rearing chicks hatched from eggs left undisturbed. But when migrating, the sandhill-reared Siberians would head for North America while the other Siberians depart for China. Like the sandhill-reared whoopers, the sandhill-reared Siberians would be expected successfully to move into the upland feeding niche and to learn the migration route of the lesser sandhills. The Siberians would be expected to return to natal areas in Yakutia and thus meet, flock, and perhaps pair with "normal" subadult Siberian cranes.

Siberian cranes apparently only rear 1 chick per year, although 2 eggs are usually laid; consequently, the foster-parent program might double the productivity of the eastern flock of Siberian cranes. Each year half of the chicks would learn to feed in upland habitats in North America unlike the "normal" Siberians that would continue to depend on the Asian wetlands. Perhaps the new wintering population would be much more adaptable, and thus successful, than the traditional Siberians.

DISCUSSION

Crane species that feed in upland agricultural fields in winter are typically successful species, whereas species that depend on aquatic habitats in winter are less successful. Will the Siberian cranes be able to shift to the sandhill niche? The only clue to this concern is derived from observations of several Siberian cranes that accidentally migrated to Japan and joined flocks of white-naped and hooded cranes (*Grus monacha*) at the crane feeding station on Kyushu Island. For several decades the Japanese Government has sponsored the winter feeding programs for cranes. Several thousand birds congregate on a few hectares of agricultural lands where they are fed a variety of dry grains that are hand-scattered over the field each morning. The Siberian cranes fed on the grains with the other crane species and in spring they migrated north. The Siberians can survive on upland foods if they learn to feed through association with crane species that feed in uplands. This is encouraging evidence that Siberian cranes could survive with lesser sandhills on their arid winter habitats in North America.

In sharp contrast to the above example, however, are 2 lone subadult Siberian cranes that wandered to Japan during migration but that did not find flocks of other crane species. These cranes remained in flooded rice paddies and vainly probed in the mud for sedge tubers. The weakened birds were captured and taken to zoos; otherwise they undoubtedly would have perished. They did not know how to feed on available upland food items but had continued to unsuccessfully search for tubers in shallow water habitat.

A 2nd concern is relative to the possible interaction of the Siberian crane and the whooping crane if they happened to meet during migration. Both cranes are white with black primary flight feathers and, based on such superficial evidence, they might be mutually attracted. However, recent studies on the comparative ethology and morphology of cranes indicate that the Siberian crane is distantly related to species of the genus *Grus*, shows greatest affinities with the wattled crane (*Bugeranus carunculatus*), and is now classified as *Bugeranus* (Archibald 1976a, Wood 1979). The calls of the Siberian crane are soft and flutelike, whereas the *Grus* typically have harsh, shrill calls. Likewise the threat postures and dances of the Siberians are highly distinctive from *Grus* visual displays. The trachea of *Grus* species coils extensively in the sternum, whereas in the Siberians and wattled cranes the trachea makes only a slight indentation in the top of the sternum. These marked differences in behavior and anatomy would undoubtedly help serve as reproductive isolating mechanisms between Siberian cranes and whoopers.

The species also would be geographically isolated in their breeding distribution. Migratory cranes return to nest in their natal areas. The Siberian cranes are expected to return to northeast Asia to nest about 11,425 km west of the breeding grounds of the whooping cranes in Wood Buffalo National Park (WBNP), Canada. It could be argued that, if pairing occurred during migration and the pair bond exceeded in strength the drive to return to natal areas to breed, whoopers might be led to Asia or Siberians to WBNP. Evidence from closely related sandhill crane subspecies that mix in flocks on migration and on their wintering grounds, yet maintain subspecies identity, indicates that pairing very likely occurs on or enroute to the breeding grounds and not elsewhere (Tacha pers. comm. 1981). Quite likely, pairing in other species likewise occurs on the nesting grounds. This leads 1 to conclude that there is little risk of interbreeding between whoopers and Siberians.

The hunting of sandhill cranes in Alaska, Saskatchewan, the Central Flyway States, and Texas would be a threat to the Siberian cranes.

In the Central Flyway, large flocks of sandhill cranes migrate south in September in advance of the movements of the whoopers that usually migrate from early October through early November (Archibald 1976b). Sandhill hunting is opened in advance of the arrival of the whoopers and as soon as a whooper is observed hunting is discontinued until the whoopers have departed. The Siberian cranes would migrate in company with the sandhills and thus present possible complications in the hunting regime. Curbing sandhill hunting might create opposition from some hunters not interested in crane conservation, and perhaps the security of both the whoopers and Siberian cranes would be threatened by such persons. Certainly the shooting of Siberian cranes in Canada or the USA would not be understood in the USSR, China, and India where Siberian cranes are treasured and protected.

Finally, the introduction of a species into a geographic area to which it was never known to be native must be approached with care. The Siberian crane will only be introduced as a migrant and winter visitor. The migration and winter habitat of the lesser sandhill crane consists predominantly of harvested agricultural fields where there is an abundance of food. If the Siberian crane adapts to the sandhills' niche there will be an abundance of food for both species. Thus the Siberian crane probably will not compete for resources with North American species.

CONCLUSION

Despite the potential biological problems in this project, the risks may be justified if the wild Siberian crane populations continue to decline. Certainly a Siberian crane flock breeding on their traditional breeding grounds in Asia, but wintering in North America, is a preferred option to extinction of the species in the wild. The lesser sandhills of eastern Siberia provide that option. To better assure the security of cross-fostered Siberians, the sandhills should be color-marked in eastern Siberia and then monitored enroute to and through North America. By knowing the migration route(s) and migration dates of the potential foster-parent population of sandhills, care can be taken in North America to mould crane hunting so that it poses a minimal risk to Siberian cranes. The program offers an opportunity for scientific cooperation and good will between North American and Asian nations in an age when cooperation among the superpowers is essential to preserve life on earth as it is now known.

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INTRODUCTORY REMARKS

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The Platte River Whooping Crane Habitat Maintenance Trust (Trust) is a private, nonprofit organization formed to restore and preserve migratory bird habitat in the Big Bend area of the Platte River in Nebraska. The species of primary interest is the whooping crane (*Grus americana*); however, the Trust is charged with protecting habitat for all migratory birds using the Big Bend area, including sandhill cranes (*Grus canadensis*), ducks, geese, least terns (*Sterna albifrons*), bald eagles (*Haliaeetus leucocephalus*), and others. The Trust was formed in 1979 as an element of the settlement of litigation regarding the potential effects of the Grayrocks Dam and Reservoir, in Wyoming, on the Nebraska habitat of the whooping crane and other migratory birds.

The court settlement which created the Trust allowed the Trustees considerable discretion in meeting the Trust's purposes. The Trust may fund projects or activities which include, but are not limited to, management of crane habitat, acquisition of land or interest in land, conduct of scientific studies, and acquisition of rights to water or water storage. The settlement, however, explicitly required the Trustees to do the following:

(a) Establish a written habitat monitoring plan which can be used to describe changes in riparian, wetland, and island habitat utilized by sandhill and whooping cranes within the Platte River. The plan shall be reviewed by appropriate federal, state, and private agencies, including the U.S. Fish and Wildlife Service, and the Nebraska Game and Parks Commission, concerned with the natural resources of the Platte River in the area;
(b) Institute the habitat monitoring plan under the supervision of a technical steering committee comprised of qualified ecologists and water resource specialists selected by the Trustees; and
(c) Prepare habitat monitoring reports for public distribution on a regular basis.

The following 2 papers summarize work conducted to date on fulfilling the requirements stated above. The 1st paper (Armbruster and Farmer) provides the documentation for a sandhill crane habitat model for the Platte River. Sandhill crane habitat requirements and relative importance were defined using the U.S. Fish and Wildlife Habitat Suitability Index Model methodology.

The 2nd paper (Ellis and Shoemaker) explains how the habitat suitability model influences the content and organization of the Habitat Monitoring Plan. The Monitoring Plan is oriented toward the use of remote sensing techniques and automated mapping to provide a data base for the monitoring program. The habitat suitability models provide a mechanism for assessing migratory bird habitat quality through time.

These 2 papers were distributed to a group of peer reviewers at a 25 August 1981 evening session, organized by John VanDerwalker, Executive Director of the Platte River Trust. The primary purpose of this session was to review the sandhill crane model assumptions. The authors wish to acknowledge the very beneficial participation of the reviewers (see List of Participants). Comments received during this session will be incorporated into the next draft of the habitat model. The authors also thank John VanDerwalker of the Trust for support and guidance in developing these presentations.

LIST OF PARTICIPANTS

Persons invited to the evening work session were those especially knowledgable about sandhill cranes that use the Platte Valley Area. The individuals present were George Archibald, Mike Armbruster, Dave Blankinship, Scott Derrickson, Ken Diem, Rod Drewien, Scott Ellis, Tom Eschner, Dick Hadley, Ron Kauffeld, Eugene Knoder, Gary Krapu, Jim Lewis, Gary Lingle, Carroll Littlefield, Tom Mangelson, Duane Schroufe, Len Schuman, Tom Shoemaker, Tom Tacha, Jake Valentine, and John VanDerwalker.

DRAFT SANDHILL CRANE HABITAT SUITABILITY MODEL

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Abstract: A draft habitat suitability model for sandhill cranes (*Grus canadensis*) was developed for use on the spring staging areas of the Platte River in central Nebraska. The model identifies grain food, invertebrate food, and roosting requirements as critical habitat components. Grain food is supplied by cropland cover types (corn and sorghum stubble, and wheat), invertebrate food by grasslands and alfalfa fields, and roosting requirements by the channel or riverine habitat. Factors modifying the availability of these resources are identified. The model was developed to operate on data obtainable from aerial photographs; therefore, most variables are of a spatial format. Mechanisms are presented for obtaining a single numerical value representing habitat suitability.

A modeling seminar was held 2 and 3 June 1981 in Fort Collins, Colorado, to develop a draft habitat suitability model for sandhill cranes. Participants included Rod Drewien, University of Idaho; Chuck Frith and Jim Lewis, U.S. Fish and Wildlife Service; Ross Lock, Nebraska Game and Parks Commission; Tom Shoemaker, Environmental Research and Technology, Inc.; and John VanDerwalker, Platte River Whooping Crane Habitat Maintenance Trust. The authors served as discussion leaders. Specific objectives were -

1. To develop a draft habitat suitability model for sandhill cranes in the Platte River Valley that will operate on remotely sensed data.
2. To document the assumptions of the draft model including those necessary to extend the model to include whooping crane (*Grus americana*) habitat requirements.
3. To identify a potential approach for subsequent testing and verification of the model's performance with actual sandhill crane use data.

The purpose of this report is to document the draft sandhill crane habitat model developed during the seminar. Whooping crane habitat relationships will be discussed at the end of the report. This work was requested and partially funded by the Platte River Whooping Crane Habitat Maintenance Trust through Cooperative Agreement No. 14-16-0009-81-999 with the U.S. Fish and Wildlife Service. We wish to thank the above named participants for their patience and dedication to the task of developing this model. We also extend our appreciation to G. Krapu for technical assistance, J. Lewis and P. Sousa for editorial advice, and D. Ibarra and C. Gulzow for typing earlier drafts of the manuscript.

METHODS

The model described below was developed following the conceptual framework used by the Habitat Evaluation Procedures Group of the Office of Biological Services, U.S. Fish and Wildlife Service. It is assumed in this approach that habitat suitability, or a specific area's ability to supply the life requirements for selected species, can be numerically described. This description can be accomplished by sequentially subdividing "habitat" into conceptually manageable subcomponents, and then identifying sets of field-measurable variables and the functional relationships which quantitatively define the species' habitat requirements. Functional relationships in the model are constructed so that measured variables are compared to perceived optimum conditions. Optimum conditions are those thought to be associated with the highest actual or potential densities of the species within a defined area. Comparison of measured to optimum conditions results in an index for each habitat subcomponent which can be ultimately aggregated into 1 habitat suitability index (HSI). The HSI can be interpreted as a relative measure of the number of animals that could potentially be supported by the unit of habitat under study.

Model development occurred in 3 phases and is presented here in that same sequence. The phases are: (1) establishment of model objectives; (2) identification of model variables; and (3) establishment of the functional relationships between model variables.

ESTABLISHMENT OF MODEL OBJECTIVES

This introductory phase serves to set the rules, or bounds, for model development and subsequent application. Specifically, during this phase model goals are identified and the geographic area and season of model applicability are defined.

Model Goals

A model, by definition, is a simplification of a complex system. However, if constructed properly the model can be used to progressively improve our understanding of the system it mimics. As understanding is acquired, detail can be added until the level of model complexity (i.e., calibration) required to meet original objectives is reached. Thus, a model should have at least 2 goals; an acceptable short-term goal that permits improvement of understanding, and an ideal goal that will meet objectives but may require a long-term effort.

Seminar participants identified an acceptable short-term goal as the informal presentation of their draft model at the 1981 National Crane Workshop to be held in late August in Grand Teton National Park, Wyoming. The purpose of the presentation was to obtain peer review and input, with the ultimate goal of an improved and generally acceptable draft working model. Participants identified a long-term goal as the use of the model to predict the outcome of management activities designed to maintain or improve sandhill crane habitat along the Platte River. This long-term goal is pursued through testing the model against crane-use data and by long-term monitoring of crane responses to management actions.

Geographic and Seasonal Applicability

Participants identified the primary area of model applicability as a 5.6-km band on both sides of the Platte River between Overton and Chapman, Nebraska. Other areas were also identified (1) in the vicinity of Lake McConaughy, near Lewellen, and (2) between Sutherland and North Platte, Nebraska. The period of model applicability was defined as the time when sandhill cranes use the Platte River as a spring staging area, mainly 15 March to 15 April. However, collection of some model variable data could fall outside this time frame.

IDENTIFICATION OF MODEL VARIABLES

The process of simplifying a complex system often translates into decisions concerning what variables to leave out of the model rather than what variables to include. Study constraints, including time and money, assisted seminar participants in limiting potential variables for the draft model. It was decided that the model would operate on data obtainable from aerial photographs. Any other data would have to come from existing sources, such as flow regime information from gauging stations operated by federal or state agencies. It was recognized that such restrictions could limit the model's predictive reliability.

The sequential subdivision of habitat subcomponents into measurable variables is facilitated through the consideration of simple habitat relationships. In this approach, the relationships between habitat requirements, such as food and water, and the surface cover types from which they originate, are 1st identified. Next, characteristics of those cover types that in some way relate to the supply of habitat requirements are identified as potential model variables. Final selection depends on the modeler's ability to describe the functional relationships of potential model variables to habitat suitability, and to obtain measured values within study constraints. This process, as used by the seminar participants, is discussed below along with the appropriate functional relationships.

Habitat Requirements

Seminar participants identified 3 requirements they considered critical in supplying optimum spring staging habitat for sandhill cranes along the Platte River. These requirements included grain food, invertebrate food, and roosting requirements. Food was treated as 2 separate subcomponents in response to studies which have speculated on the synergistic importance of both (Reinecke and Krapu 1979). It was generally agreed that roost sites were the key habitat subcomponent and that several measurable variables could be readily identified.

The importance of loafing requirements (including drinking water) was discussed at length by seminar participants. It was noted that ideal conditions exist if certain cover types used for loafing were located adjacent to or in close proximity to roost sites. However, these same cover types were also used for feeding. Therefore, the 1st major assumption of the model was that loafing requirements would never be more limiting than roosting and feeding requirements; i.e., if roosting and feeding requirements were met, then loafing requirements would also be met. Thus, loafing requirements were not formally identified in this model as a critical subcomponent of spring sandhill crane habitat.

Cover Types

Potential model variables were limited earlier to those values readily obtainable from remotely sensed map data. Seminar participants anticipated that this limitation would require the structuring of most model variables into a spatial format, i.e., the amounts available of particular cover types supplying habitat requirements, and distances between such points of interest. Thus, identification of mappable cover types, related to the habitat requirements of sandhill cranes, became an extremely important task in model development.

The following discussion 1st defines cover types from which previously identified habitat requirements originate. It then defines an additional cover type identified by seminar participants as functioning in adjusting the values of those requirements. Values and adjustment factors will be discussed later under model variables.

Cover type origins of habitat requirements.--Seminar participants identified cropland, alfalfa, grassland, and riverine types as the potential supply sources of at least 1 habitat requirement.

Sandhill cranes obtain grain food from nontilled (stubble) grainfields. Grain food consists almost entirely of corn, with lesser amounts of sorghum and wheat also taken (Fritzell et al. 1979, Lewis 1979, Reinecke and Krapu 1979). Therefore, data bases generated from aerial photography must delineate cropland (corn and sorghum stubble, and wheat) as a major cover type.

Invertebrate food, in the form of earthworms, beetles, grasshoppers, cutworms, and snails, accounts for approximately 4% of the composite spring diet of sandhill cranes staging along the Platte River (Reinecke and Krapu 1979). Although this constitutes a relatively small percentage of the total diet, time budget analyses by Reinecke and Krapu (1979) indicate that cranes expend over one-half of their daily foraging effort in obtaining this food source. This relatively large expenditure of effort for so small a percentage of the total diet constituted the basis for inclusion of invertebrate food as a distinct habitat requirement in the draft model.

Reinecke and Krapu (1979) found that invertebrate food was obtained almost exclusively from grasslands (tame and native) and alfalfa fields. Other researchers working on the Platte have obtained similar results, but also have indicated the importance of moisture, i.e., the more mesic sites, or "wet meadows," being preferred by sandhill cranes (Frith 1976, Lewis 1979). Participants identified alfalfa as a required model cover type, but agreed to postpone any classification of grassland until it could be determined what level of moisture regime separation (i.e., mesic to xeric conditions) was possible from aerial photography. It is anticipated that some of the more mesic grasslands may be distinguishable as the Emergent Wetland-Temporarily Flooded category of Cowardin et al. (1979:30, the Type 1 of Shaw and Fredine 1956).

Sandhill crane roosting requirements are supplied by the river channel, as modified by the presence of vegetation (Frith 1974 in Aronson and Ellis 1979). Seminar participants agreed on the need to subdivide within-channel roosting habitat into 3 separate cover types: (1) open riverine--either open water or bare sand; (2) riverine with vegetation <1 m in height; and (3) riverine with vegetation >1 m in height.

Cover types which modify the value of habitat requirements.--Seminar participants identified woody vegetation, subdivided into categories of <1 m or >1 m in height, as cover types which may modify the value of habitat requirements supplied by the types (cropland, alfalfa, grassland, and riverine) discussed above.

Model Variables and Their Values

"Contrary to the feelings of many . . . when it comes to modeling complex nature, information about only a relatively small number of variables is often a sufficient basis for effective models . . . " (Odum 1971:7). Thus, it became the task of seminar participants to identify and limit potential model variables to those which not only could be evaluated from aerial photography, but also would serve to represent in aggregate the quality of value of specific units of habitat for sandhill cranes. The following discussion presents the sandhill crane habitat requirement variables identified by seminar participants, the logic and assumptions associated with each, and their respective values.

Grain food variables.--Grain foods occur in croplands predominately used for corn production. The potential variables considered were tillage regime, type of crop, and amount (area of crop type). Seminar participants felt the availabiltiy of grain food for sandhill cranes was not a problem because most areas supported spring-tilled corn. Therefore, it was assumed that the only significant variable was the area of cropland, and that all croplands support grain of equal value to cranes. However, technological improvements in harvesting equipment or land-use changes in the future could alter this situation and precipitate model revisions.

The total area of cropland is not synonymous with the area available for crane use. Cranes are intolerant of certain human disturbance factors which, if present, render segments of cropland unavailable. This is a behavioral characteristic manifested as avoidance of an area around the respective disturbance. For purposes of delineating the available area of grain food, this biological relationship can be translated into zones of varying widths around disturbance factors identified from aerial photos. These zones supply no usable grain food for sandhill cranes. The disturbance factors and widths of zones identified by seminar participants as supplying no grain food are presented in Table 1. Note that zone widths vary, reflecting the differential response of cranes to different types of disturbances.

Finally, participants noted that the presence of a visual barrier between the disturbance factor and cropland eliminates the avoidance response. A visual barrier is defined as woody vegetation >1 m in height. Therefore, the existence of the above cover type between a disturbance factor and cropland makes the entire cropland (up to the visual barrier) available for crane use.

Invertebrate food variables.--Seminar participants discussed the relative abilities of alfalfa and grassland cover types to supply invertebrate food for sandhill cranes. As discussed previously, there was a general feeling that the more mesic grassland types were probably better crane habitat, in terms of invertebrate food, than were either alfalfa or the more xeric grassland types. Therefore, the mesic areas should be more valuable and have a higher rating or weight than the drier sites. However, substantiating data for this premise are not available. Participants therefore agreed to postpone any weighting scheme for cover types supplying invertebrate food until more information becomes available. Thus, the variable of interest for invertebrate food is the area of alfalfa and grassland cover types available for crane use.

Seminar participants believed that the human disturbance factors applicable to alfalfa and grassland cover types were the same as those used to adjust total area of available cropland (Table 1). However, it was noted that cranes tolerated even less disturbance while using invertebrate food cover types. Therefore, the zones of disturbance used to adjust available alfalfa and grassland are larger. The presence or absence of a visual barrier will also affect the use or avoidance of alfalfa and grassland types, just as it functioned for cropland. Thus, woody vegetation >1 m in height is applicable as a visual barrier for alfalfa and grasslands.

Variables associated with roosting requirements.--Participants identified 3 variables which characterize the roosting requirements of sandhill cranes. These variables relate primarily to how the riverine cover type supplies security to the birds while they are using the channel for roosting. The variables deal with the amount of area available, the depth of water, and the potential for human disturbances.

Cranes rely heavily on the eyesight of flock members to detect potential danger. This defense mechanism works best in terrain where potential predators can be detected before the flock is threatened. This relationship translates into a requirement for some minimum area of unobstructed view. A visual obstruction for sandhill cranes is vegetation, a stream bank, or any other visually solid object >1 m in height. Seminar participants felt that cranes require at least 25 m of unobstructed view in all directions before they will use a channel for roosting. This means that the minimum area needed for roosting is 25 m in radius, or a minimum unobstructed channel of 50 m. Optimum conditions occur when at least 75 m or more unobstructed view exists, or a minimum unobstructed channel width of 150 m. These estimates are based on actual crane-use data (U.S. Fish and Wildlife Service 1981).

Sandhill cranes prefer to roost on submerged sandbars within the river channel. Seminar participants identified depth of water as an important variable and agreed that the optimum water depth for roosting ranged from 10.2 to 20.3 cm. Water deeper than 35.6 cm is considered unsuitable for roosting. Some use of bare sand occurs but it is assumed that it will never be more than one-half the value of optimum water depths.

Most of the variables identified thus far (e.g., amount of cropland, presence or absence of vegetation >1 m, or width of unobstructed channel) lend themselves well to interpretation from aerial photography. This is not true for depth of water. Flow in the Platte is a dynamic variable changing between months, weeks, day to day, or even hourly. Therefore, depth conditions depicted by aerial photography at 1 instant in time may be meaningless when extrapolated to the 1-month to 6-weeks period of spring crane use. Participants agreed that values for this variable should be

Table 1. Types of disturbances resulting in avoidance of cover types by sandhill cranes and the size of affected areas.

Type of disturbance	Width (m) of affected area[a]	
	Cropland	Alfalfa and grassland
Paved road	100	200
Gravel road	50	100
Private road	10	20
Urban dwelling	200	400
Single dwelling	50	100
Railroad	100	200
Commercial development	200	400
Recreational area	50	100
Highlines	10	20
Bridges	100	200

[a] Width of a band on both sides of a disturbance factor, or the radius around a single point.

Table 2. Types of disturbances influencing use of potential riverine roost sites by sandhill cranes and the size of affected areas.

Type of disturbance	Width (m) of affected area[a]
Paved road	400
Gravel road	200
Private road	40
Urban dwelling	800
Single dwelling	200
Railroad	400
Commercial development	800
Recreational area	200
Highlines	40
Bridges	400

[a] Width of a band on both sides of a disturbance factor, or the radius around a single point.

obtained from sources other than aerial photography. These data will be obtained from a hydrological submodel which integrates flows as measured at various gauging stations, with stream width to obtain a mean depth for various cross sections of channel. Work is currently underway to develop the hydrological submodel in cooperation with the U.S. Geological Survey.

Seminar participants identified the potential for human disturbance as the last of 3 variables characterizing the ability of the riverine cover type to supply roosting requirements. An otherwise optimum roost site (i.e., optimum unobstructed area and optimum water depths) will not be used by cranes if located too near a source of human disturbance. Table 2 lists the disturbance factors which should be considered and their respective zones of influence. It should be noted that, as with cropland, alfalfa, and grassland, the presence of a visual barrier between the disturbance factor and the river channel may eliminate the disturbance potential. Visual barriers are woody vegetation >1 m in height.

Overall Habitat Suitability

The final step in the identification of model variables involves considering the location of habitat requirements and the relative amounts of cover types supplying these requirements. Optimum habitat conditions occur when requirements are in close proximity and the supplied resources (e.g., food) are at or above some defined level.

Juxtaposition.--Juxtaposition or the proximity of cover types can be characterized in terms of distances between the cover types of interest. As noted previously, seminar participants identified roosting requirements as the key subcomponent of spring staging habitat. Therefore, the focal point of the model becomes potential roost sites, and any juxtaposition variables should deal with the location of cover types potentially supplying grain and invertebrate food, i.e., their location in terms of distances from roosting sites. Seminar participants felt that optimum juxtaposition occurs when both grain and invertebrate food sources are located within 1.6 km of the roost site; between 1.6 km and 5.6 km suitability is assumed to decrease linearly. Food resources located 5.6 km from the roost site are assumed to be only one-tenth as valuable to cranes as those located within 1.6 km.

Composition.--Composition is the relative proportion or percent of an area which provides an identified habitat requirement (e.g., grain food). Seminar participants agreed that estimates of optimum percent composition for each habitat requirement needed some type of substantiating data. Subsequent evaluation of area estimates for various cover types along the Platte River between Kearney and Grand Island, Nebraska, have provided some relative values for present conditions. These are extremely gross estimates of optimum percent composition, and are presented here to serve as a focal point for discussion and future refinement. These estimates are: 55% cropland (grain food), 35% grassland and alfalfa combined (invertebrate food), and 5% riverine (roosting requirements).

ESTABLISHMENT OF THE FUNCTIONAL RELATIONSHIPS BETWEEN MODEL VARIABLES

Habitat suitability will be evaluated by combining model software with computer capabilities in order to interpret spatial data. The specifics of such an approach are beyond the scope of this report; however, such capabilities do exist and require only the interpretation of aerial photography, digitization of appropriate cover types, and data entry. In the following section, the functional relationships between previously identified variables are described and a mechanism is presented for combining these values into a single aggregate index representing habitat suitability for sandhill cranes. The discussion is basic with an emphasis on concepts rather than the actual mechanics of data manipulation which are largely automated. The functional relationships associated with habitat requirements, i.e., grain and invertebrate food, and roosting, are presented 1st followed by a discussion of how juxtaposition and composition considerations will adjust these variables into a single value for habitat suitability.

Food Relationships

No variables were defined to differentiate quality levels of cropland, grassland, or alfalfa. The variables of interest for both grain and invertebrate food are simply the usable areas of each respective cover type supplying these resources after adjustment for human disturbance. Total area of each type will be compared to the total area of all cover types under consideration within a defined area. This comparison will yield a relative percent value for each cover type supplying either grain or invertebrate food. These relative percent values will ultimately be compared to the optimum percent composition values to obtain a food suitability value for both grain and invertebrate food (see discussion of composition relationships presented below).

Roosting Relationships

The suitability of a given channel segment for roosting by sandhill cranes is a function of 3 variables: the area of unobstructed view, the mean depth of water, and the presence or absence of disturbance factors within defined distances from the channel. Optimum roosting conditions are defined as a segment of unobstructed (water, bare sand, or vegetation <1 m in height) channel $\geq$150 m wide having a mean depth between 10.2 and 20.3 cm and free from the human disturbances listed in Table 2.

In situations where values are other than optimum the relationship between the 3 variables is assumed to be compensatory whereby a low value for 1 variable is offset by high values for the others. However, if any of the values are 0.0, or unsuitable, then the overall suitability of the site for roosting should be 0.0. Thus, a geometric mean of the 3 variables is the suggested function:

$$RS = (UA \times WD \times DF)^{1/3}$$

where RS = roosting suitability of the channel segment under evaluation; UA = index value for unobstructed area; WD = index value for water depth; and DF = presence or absence of disturbance factors. Note that UA and WD are expressed as indices with values ranging from 0.0 to 1.0. Optimum values equal 1.0, while 0.0 represents no habitat potential, or unsuitability. Disturbance factors are treated differently. Only 2 values are possible for this variable; 1.0 if none of the disturbance factors listed in Table 2 are located within their respective distances of a potential roost site, or 0.0, if any single or combination of factors exists within their defined distances of the channel.

Juxtaposition and Composition Relationships

The final step in obtaining an overall habitat suitability value for a particular area of interest involves the adjustment of each habitat requirement suitability value (e.g., RS = roosting suitability) by juxtaposition and composition values. Seminar participants defined optimum conditions as the existence of adequate grain and invertebrate food within 1.6 km of roosting requirements. The suitability of food sources is adjusted downward as distances from roosting habitat exceed 1.6 km. Computerized evaluation of distances for cover types serving as potential food sources will yield adjusted (by the respective juxtaposition value) grain and invertebrate food suitability values.

The final adjustment before an overall habitat suitability value is obtained involves composition considerations. Earlier, percent composition values were presented for each of the 3 habitat requirements. The suitability values for each habitat requirement, adjusted by juxtaposition values as described above, are summed across all cover types supplying their respective requirements to calculate the total available amount of each habitat requirement. Each total is then divided by the area under study to yield percentage figures (e.g., percent of a defined study area that provides grain food). These figures are estimates of the usable habitat resources per unit area. The final operation requires the division of these estimates by optimum percent composition figures which are estimates of the habitat resources per unit area required to support a perceived optimum population density of cranes. An index value between 0.0 and 1.0 is obtained for each habitat requirement. It is assumed that the lowest habitat requirement suitability value resulting from these adjustments represents the overall sandhill crane habitat suitability of the area under study.

DISCUSSION

The purpose of this report has been to document a draft sandhill crane habitat suitability model developed earlier this year by a group of individuals knowledgable of the species and its needs while staging each spring along the Platte River in central Nebraska. Critical habitat requirements were identified as grain and invertebrate food, and roosting requirements. These requirements are currently provided by croplands, alfalfa fields and grasslands, and the river channel. The model was developed to operate on data obtainable from aerial photography; therefore, most variables representing critical habitat requirements are in a spatial format. The final output from the model is a single value, the habitat suitability index (Fig. 1). This index can be interpreted as a relative measure of the number of sandhill cranes that could potentially be supported by any specific unit of habitat.

This report completes the initial documentation of the model. However, there remains the task of evaluating the models' performance. The reader has undoubtedly identified several areas where further definition is required. One of these is the area of disturbance factors and visual barriers. Is there a minimum width required before an assumed visual barrier becomes functional? Recent work in the eastern United States indicates that distances and visual barriers may be more complicated than the simple relationships assumed here (Lovvorn and Kirkpatrick 1981). Other questions involve the size of a study area, the use of exposed sandbars as opposed to submerged bars, and composition values more in tune with crane energetics. The answers to these and other questions will be pursued as work is initiated in 1982 to evaluate and ultimately calibrate the model presented in this report.

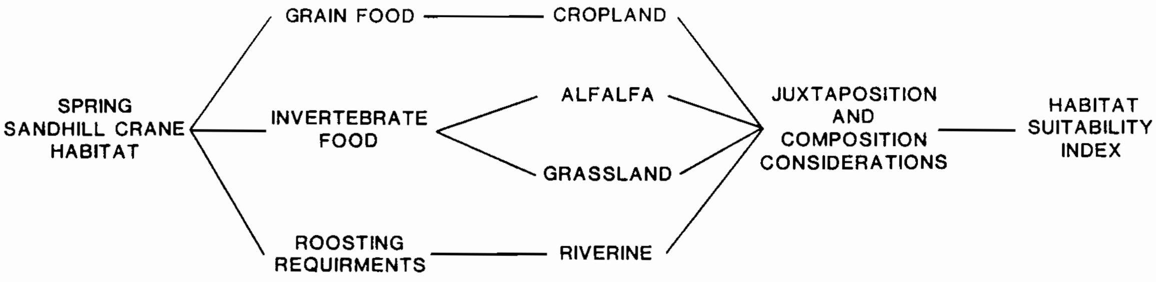

Fig. 1. Habitat requirements, cover types, and spatial considerations used to describe sandhill crane habitat.

WHOOPING CRANE HABITAT RELATIONSHIPS

The 2nd objective of the seminar called for the documentation of the sandhill crane model complete with any additional assumptions needed for a model of whooping crane habitat. As seminar participants developed the model it became clear that the level of data detail available for sandhills did not exist for whooping cranes. The 2 species appear to use entirely different strategies for exploiting resources during migration. There does not appear to be enough data available on whooping crane habitat requirements during migration to develop a model similar to the draft presented here for sandhill cranes. Seminar participants identified human disturbance as an important variable to consider but could go no further in identifying other habitat requirements. It appears a great deal of work is required if we are to understand the habitat needs of migrating whooping cranes.

Drewien and Bizeau (1981) studied habitat use of whooping cranes migrating from Grays Lake, Idaho, to wintering grounds in New Mexico. The radio-tagged birds were followed by aircraft. In the fall of 1981, radio-tagged whooping cranes are being followed from Wood Buffalo National Park, Canada, to their wintering grounds on the Texas coast. It is hoped that these studies will provide the 1st of the data required to describe habitat needs of migrating whooping cranes.

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DRAFT HABITAT MONITORING PLAN FOR THE PLATTE RIVER WHOOPING CRANE HABITAT MAINTENANCE TRUST

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Abstract: A draft Habitat Monitoring Plan was developed to meet the management needs of the Platte River Whooping Crane Habitat Maintenance Trust. The Plan contains the following major elements: an automated land cover:land use mapping system that is updated by periodic interpretation of new aerial photography, a map overlay system that permits comparisons of change in land cover types over time, and habitat suitability models that provide habitat quality ratings for a particular species (e.g., sandhill crane) on particular river reaches in the Trust management area. Additional habitat suitability models, and a hydrology model (river channel width maintenance) will be added to the Plan in the future.

The purpose of this presentation is to outline the major elements of the Habitat Monitoring Plan (HMP) being developed for the Whooping Crane Habitat Maintenance Trust based in Grand Island, Nebraska.

The purpose of monitoring is to gather ecological data needed to do the following:

1. Evaluate the quantity and quality of existing migratory bird habitat in the Trust's operational area.
2. Predict trends in the quality and quantity of migratory bird habitat.
3. Periodically measure the quantity and quality of migratory habitat--and compare these measures.
4. Provide information for the Trust's strategic planning efforts.

HABITAT MONITORING PLAN CONTENT

Environmental elements to be monitored are primarily determined by the habitat requirements of the principal migratory bird species that use the Platte River system. The initial step in defining crane habitat requirements on the Platte was to develop a habitat suitability model for sandhill cranes (*Grus canadensis*) because the habitat requirements of whooping cranes (*G. americana*) during migration are still poorly known. It is assumed that this model, with modifications, will also be valid for whooping cranes. The habitat suitability model for sandhill cranes was developed through discussions with biologists familiar with the Platte River System (see Armbruster and Farmer, this proceedings).

The model identifies the major habitat components that supply the needs of sandhill cranes during the spring staging period on the Platte River. These components are discussed in detail in the preceding article. Briefly, these components include the following: Food (a) invertebrate (wet meadows, grasslands) and (b) grain (croplands); roosting sites (a) open river channel (limited by minimum unobstructed view, and minimum and maximum water depth).

Constraints on crane feeding and roosting areas include a variety of human disturbances (road, houses, powerlines), as well as natural visual obstructions (tall trees). Other constraints include a the maximum distance that cranes must fly between feeding and roosting sites. Based on the crane habitat components identified above, the focus of habitat monitoring will be directed toward (1) detecting and predicting changes in quantity and quality of available or potential crane roosting habitat, and (2) detecting and predicting changes in quantity and quality of available crane feeding habitat. Other factors that influence the content of the monitoring plan include documenting the potental for, and success of, applied habitat rehabilitation efforts, and water management approaches.

HABITAT MONITORING PLAN OPERATIONAL COMPONENTS

The habitat monitoring system for the Platte River consists of a data base, and several analytical tools that extract and synthesize information for decisionmaking. Figure 1 illustrates the

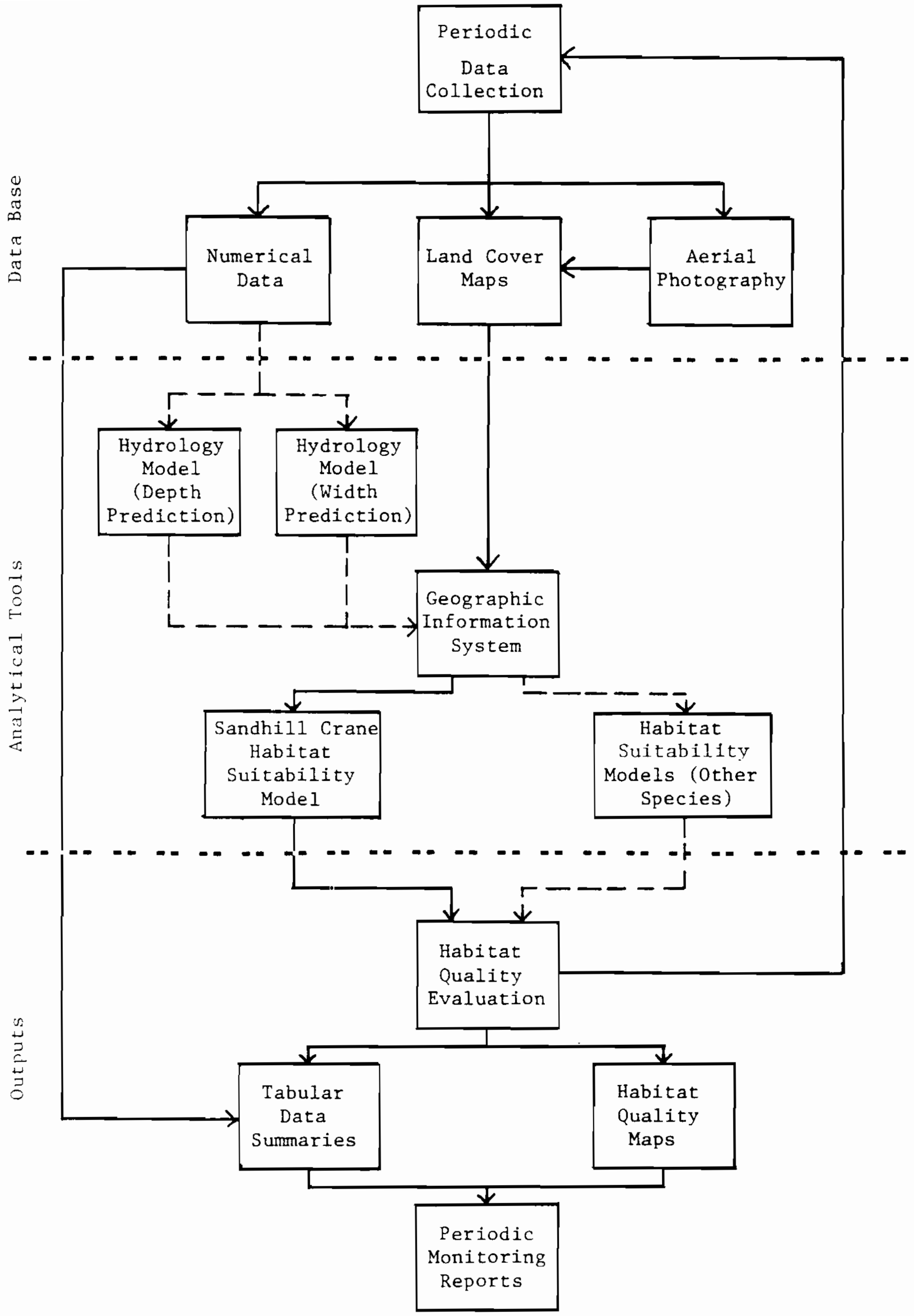

Fig. 1. Components of the Habitat Monitoring Plan for the Platte River Whooping Crane Habitat Maintenance Trust.

relationships among the various components. The characteristics of each of the components are discussed separately below.

Data Base

The initial data base for the Trust monitoring system will consist of 2 major data types: land cover maps and numerical data (e.g., crane census data, river discharge data). A land cover map data base derived from aerial photography interpretation was chosen for the HMP because of the following: (1) the large size of the study area (2,072 km^2 or more), (2) the capability to discriminate important crane habitat elements from aerial photography, (3) the need to measure change in area of key habitat components over time, and (4) compatability with past and ongoing studies on the Platte River.

The land cover classification system will be developed to meet criteria for existing and future habitat models and management needs. Land cover maps will be developed from existing and new aerial photography interpretation, and digitized for computer storage. The map data base will be updated periodically, depending upon rate of change detected in the river system, and specific management actions taken to enhance crane habitat.

The numerical data base (e.g., crane census data) is expected to be supplemented by existing data collection programs (U.S. Fish and Wildlife Service [USFWS] crane population surveys, U.S. Geological Survey [USGS] stream gaging data). The Trust will initiate its own data collection programs to help answer specific questions posed by its own activities (e.g., evaluating the effects of removing vegetation in the river channel).

Analytical Tools

The analytical tools used to manipulate the map data base will consist of 2 elements. The 1st element is a data management system that can display and compare map content. This data manager is called a Geographic Information System (GIS). The 2nd element consists of models or criteria for defining habitat availability for a particular animal.

Geographic Information System

A Geographic Information System is defined as a computerized system for storage, manipulation, and analysis of geographic (map) data. The GIS is included in the HMP because it will be a critical tool in the management of the large volume of geographic data associated with the HMP. When geographic data are input into the computer system they can be easily updated to reflect changing conditions on the Platte River or changing objectives of the Trust. The GIS has also a number of powerful analytical tools that will facilitate the habitat quality evaluation based on the Habitat Suitability Index model and which can be used to evaluate management options.

The intent of the HMP is to provide answers to the simple questions about habitat (habitat quantity, percent change over time) and to provide analytical tools for answering the more complex questions of crane-habitat interactions. The 1st step was to develop a crane habitat suitability model in which assumptions about crane habitat quantities and qualities were expressed. A 2nd step in this process was to determine the analytical capabilities in a GIS needed to properly assess habitat quality and habitat change over time. Basic analytical capabilities include the following:

1. Overlay. Needed to document changes in a land cover type or other feature over time. Also needed to examine relationships between data planes (e.g., land cover type and land ownerships).

2. Size. Needed to calculate the area of different cover classes.

3. Distance, Proximity. Needed to examine the geographical relationship between crane habitat components. This is a critical capability in examining how cranes use habitat resources. Proximity of habitat components is a key element in the crane habitat suitability model.

4. Interspersion. Needed to examine how the juxtaposition of different habitats affects crane use. Output is expressed as frequency/unit area.

5. Buffer. Needed to identify constraints in system (e.g., human dwellings, roads).

6. Composite. Needed to provide numerical weighting of habitat components for habitat quality evaluations.

Other system characteristics that are needed include:

1. Scale flexibility. Needed to compare data sets entered into the system at different scales.

2. Geographic Flexibility. Needed to locate sampling points at any location within the study area, and to freely modify sampling or study area boundaries.

3. Aggregation-Disaggregation. Needed to combine or separate different classes, depending upon the types of comparison needed.

Basic output capabilities of the Geographic Information System include the following:

1. Data Tabulation. Needed to provide numerical summaries of habitat quantity, quality, and extent of change.

2. Map generation. Needed to provide hard copy of stored base maps, and to provide results of analytical procedures (e.g., shading of certain cover classes to visually represent interspersion; overlay maps to analyze change in size and position of cover classes).

At the present, the USFWS Map Overlay and Statistical System (MOSS)(USFWS 1979) provides the needed analytical capabilities and was designed to analyze wildlife habitat problems. The MOSS software system, or a system of comparable capabilities, will be used by the Trust to analyze monitoring data, and to validate the crane model as the model evolves.

Habitat Suitability Index Models

Habitat monitoring will focus on the quality and quantity of available habitat. Assessment of habitat quality is a difficult, often subjective, process and the goals of the HMP demand explicit documentation of the assumptions and process used to evaluate relative habitat quality. The format chosen for preparation and documentation of the habitat quality evaluation criteria was the Habitat Suitability Index Model or HSI model. HSI models have been developed in recent years for a variety of species for use in the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures. The HEP Group, part of the Western Energy and Land Use Team in Fort Collins, Colorado, was contracted by the Trust to prepare a HSI model for sandhill cranes on the Platte River. Background data gathering and model documentation were completed by HEP personnel; however, the majority of the model content and structure is based on an intensive 2-day workshop attended by noted crane researchers and state, federal, and private groups cooperating with the Trust.

A model is generally an abstraction of reality used as a tool to improve both our understanding and predictive capability about functioning systems (Habitat Evaluation Procedures Workbook, unpublished). In this instance, the system of interest is the species-habitat relationships for sandhill and whooping cranes on the Platte River, Nebraska. The model represents a synthesis of available information on factors affecting habitat use by cranes in the Trust study area. The HSI model format was chosen as a vehicle for habitat quality evaluations because it: (1) documents the habitat quality evaluation process, (2) establishes the level of credibility of the evaluation, (3) provides a permanent record of the basis for decisions based on habitat quality evaluations, (4) synthesizes habitat information for cranes on the Platte, (5) provides improvement incentive, (6) establishes a testable scientific hypothesis, (7) is compatible with the land cover classification mapping system, (8) functions with data that may be obtained from aerial photography interpretations, and (9) supports the planning and habitat management functions of the Trust.

The HSI model for cranes focuses on the physical and biological characteristics of habitats used by cranes for night roosting and feeding. Model variables focus on well-known parameters of concern to crane biologists, such as visual characteristics of roost sites, the degree of isolation from human disturbance, interspersion between roosting and feeding habitats, and the optimum mix of habitat types used by cranes. A more extensive discussion of model assumptions and applications is supplied in Armbruster and Farmer (this proceedings).

It is the intent of the HMP that other species habitat suitability models will be developed in the future as management actions in the river are applied and more information is obtained to support model assumptions.

Platte River Hydrology Models

The relationships between migratory bird habitats and water use in the Platte River ecosystem are critical factors to consider in the HMP. Several authors (Frith 1974, Williams 1978, Karlinger et al. 1981) have discussed the importance of Platte River flow conditions in determining the rate and direction of vegetative succession patterns within the river channel. The relationships between river flow, channel pattern, and the availability of crane roost habitat are very complex and have been the focus of intensive recent study by the USGS. The results of those studies are just beginning to be published so only general statements can be made about water use parameters to be included in the HMP. Detailed plans for water monitoring should be developed when USGS study results are published.

Inclusion of river flow parameters in the HMP is based on 2 main considerations. First, the river and other water areas in the study area are important habitats for migratory birds. However, these habitats are extremely dynamic and the static picture provided by aerial photographs does not adequately characterize habitat conditions. Second, river flow is believed to be an important factor in maintenance of channel width and control of vegetation establishment within the river channel. Accordingly, river flow at certain periods of time may provide an important indicator of the need to initiate a habitat monitoring cycle. Recommended water use parameters are discussed below.

Water depth relationships.--An important quality of crane roosts is that they be submerged under less than 45 cm of water. Unfortunately this quality is difficult to measure on aerial photographs (without extensive correlation to simultaneously taken ground measurements) and fluctuates greatly with river flow. In the HSI model for cranes it was assumed that water depths are acceptable in any given reach if channel width criteria are met. This relationship appears generally to be true considering recent river discharges during the spring staging period, but it should be verified and monitored in the HMP.

Recent USGS work (Karlinger et al. 1981) demonstrated the application of theoretical equations which can be used to relate river discharge, channel width, and water depth. It appears that the same relationships could be used to generate a threshold range of river discharge values which provide acceptable water depths in channel areas which meet channel width suitability criteria for crane use. These threshold ranges would need to be calculated for the USGS gaging station at Overton and possibly other gaging stations in the Trust study area. Monitoring efforts would thus consist of comparisons between measured and threshold daily discharge records for each gaging station for the spring staging period (late February to early May). These comparisons would provide a valuable check on a basic assumption of the HSI model for cranes.

Channel width relationships.--The unobstructed channel width of the Platte River is a key factor affecting distribution of sandhill cranes. Accordingly, maintenance of channel width is a subject of critical importance to the management and preservation of crane habitat on the river. The USGS work mentioned above (Karlinger et al. 1981) was directed at this problem and demonstrated an approach for calculating river discharge (effective discharge) needed to maintain a predetermined channel width within specified river reaches. The authors also addressed the question of the required flow duration for the effective discharge. The process described by the USGS appears to be a key step in management of crane habitat on the Platte and in the HMP. If effective discharges and required flow duration are calculated for key reaches on the Platte, these can be considered threshold values for an indicator system for future channel width changes. River discharge can be monitored at the appropriate USGS gaging stations and the data used to compare actual discharge to the threshold values. Failure to meet the threshold flows and duration may then be a triggering mechanism for initiating renewed habitat monitoring efforts.

HABITAT MONITORING PLAN IMPLEMENTATION

Base-line Phase

The HMP is implemented in 2 phases: base-line and future. The base-line phase will require extensive effort because the elements of the HMP are not currently active at any location. Thus the base-line phase entails work in developing and integrating the HMP elements as well as application to an initial data base. Major tasks involved in the base-line phase involve the following: (1) selection of appropriate group(s) to complete work; (2) acquisition of existing aerial photography and land cover maps; (3) revision of MOSS software to best fit overall Trust requirement; (4) digitization of land cover maps; (5) application of HSI models and map production; (6) validation of HSI models; (7) development of threshold values for water use parameters; and (8) preparation of base-line monitoring report.

USFWS Platte River Ecology Study efforts have produced adequate aerial photography coverage and partial land cover mapping of acceptable technical quality to initiate the land cover data base. The base-line land cover data base will consist of these products to the extent feasible. Development of base-line data for wildlife populations, water, and land use parameters will be based on the results of the 3-year USGS, USFWS, and Bureau of Reclamation interagency Platte River research program. Based on the strategic planning needs of the Trust, the base-line data acquisition phase will be initiated in fiscal year 1982.

Future Applications

Future monitoring efforts will be needed to update data bases used in the base-line analysis so that a summary of habitat quantity and conditions can be prepared at least on a yearly basis. However, it is not intended that the entire data base, including aerial photography, be revised each year. Rather, the design of the system, especially the computer-based GIS capabilities, emphasizes the ability to update small portions of the data base at will. This provides the flexibility to update the data base as needed, according to results of qualitative surveys, knowledge of land use changes, or interpretation of new aerial photography for a limited part of the study area.

An annual aerial survey will be conducted. The purpose of this survey is to detect significant changes in habitat, based on comparisons between observed ground features and previously mapped features. This survey will be conducted by the HMP Steering Committee or other qualified group. This group will have responsibility for deciding whether an observed change on the ground is significant in determining potential crane or migratory bird use. The survey will be conducted once (or more frequently if conditions warrant) during the growing season when crops are easily identified. The procedure will consist of flying transects along the Platte River from Overton to Chapman to document any important changes in land cover since the previous survey. The survey is intended to be qualitative and will focus on important crane and migratory bird use areas.

If changes observed appear to be significant, a special aerial photography flight over a limited area will be scheduled to provide documentation of this change. Land cover maps will be updated from the new photography and revised maps digitized to reflect changes. Depending upon the magnitude of change observed, reanalysis of crane habitat suitability will be conducted in the river reaches where change was detected to determine whether habitat suitability index values have changed.

It is anticipated that the entire land cover data base will be periodically updated, perhaps at approximately 5-year intervals. This effort would involve obtaining new aerial photography, interpreting, and digitizing the interpretation. The new mapping will provide a basis for directly measuring change in land cover, and documenting the degree to which habitat maintenance goals have been met.

Between major revisions, the annual surveys will provide a continuous update of important changes observed along the river. To focus monitoring efforts, several factors that affect migratory bird habitat quality should be considered. These factors are discussed briefly below.

[illegible].--This is a continuous process that is proceeding at varying rates at different locations in the Platte River channel. It is recommended that the entire channel area in the various study areas be remapped and digitized at 5-year intervals to document the influence of vegetation encroachment on crane roost habitat. This schedule should be evaluated in terms of Trust information needs and actual rates of change observed in major crane roost areas.

Land use.--Documenting land use changes outside the channel is important in estimating amount and quality of potential migratory bird habitat. The schedule for this activity should correspond to that of the channel updates. Major new human disturbances should be added to base maps more frequently and may require special aerial surveys to photograph selected portions of the study area. It is not expected that shifts in general cropping patterns will occur so rapidly that map updates will be required more often than at approximately 5-year intervals. However, in areas considered to be of special importance the actions of individuals should be monitored on the ground during each growing season. If significant land use changes occur (e.g., wet grassland to cropland) it may be necessary to update the map system.

Rehabilitation.--Trust rehabilitation efforts in the river channel should be documented on land cover maps.

Major changes in river surface flow.--Various changes in surface flow regime may warrant special land cover monitoring efforts. These include: large floods, implementation of large water withdrawals upstream, major drought periods, and major ice jams. Also included are periods which fail to meet the channel width and vegetation establishment thresholds included in the HMP. Efforts to monitor vegetation encroachment response to surface flow change will be restricted to the most improtant crane roosting areas.

Habitat Monitoring Plan Revisions

It is expected that the scope of the HMP will change as migratory bird-habitat interactions are better understood, as management strategies are developed, and as data management methods improve. The present scope of habitat monitoring is macroscale in its view. It is anticipated that future microscale (site-specific) monitoring studies will be needed. For example, these could include monitoring of patterns of vegetation encroachment in response to rehabilitation efforts, or in response to varying river surface flows over time. The HMP should also be reviewed for its utility in providing management information. The Plan must focus on the right issues. This review should be conducted after the base-line data base has been completed, and initial habitat suitability index values have been applied to different river reaches.

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THE PAST, PRESENT, AND FUTURE OF THE WHOOPING CRANE IN FLORIDA

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Abstract: Whooping cranes (*Grus americana*) have definitely occurred in the southeastern United States but Florida records, except fossils, are poorly authenticated. There is evidence to suggest that whooping cranes occurred in Florida, perhaps well into the 20th century. This fact and other biological considerations have prompted a study of the feasibility of using the resident Florida sandhill crane (*G. canadensis pratensis*) as foster-parents to a population of nonmigratory whooping cranes. A preliminary research project has begun and is projected to continue for the next 3 years before any decisions are made to proceed with reintroducing whooping cranes to Florida.

Florida supports a population of resident Florida sandhill cranes estimated between 5 and 6 thousand and winters the majority of the eastern population of greater sandhill cranes (*G. c. tabida*), which exceeds 15,000 birds. In fact, Florida is the only state with a substantial population of cranes year-round. It is interesting to speculate on the possibility that whooping cranes occurred in Florida during the recent past. Pleistocene fossils have been identified from several sites (Fig. 1)(Wetmore 1931, McCoy 1963, Olson 1972), but there are no recent specimens or sight records that are entirely acceptable (Howell 1932).

Specimens do exist (Fig. 2) from Waccamaw River (1850), South Carolina (Sprunt and Chamberlain 1949); St. Simmons Island near Macon, Georgia (12 November 1885); and another unspecified location (Burleigh 1958). Sight records exist for several Alabama locations: Cypress Slough on the Warrior River before 1890, Prattville in 1899, and winter records for Dauphin Island (Imhof 1962). There is also a record of a whooping crane seen at Bay St. Louis, Mississippi, on 15 April 1902 (Burleigh 1944)(Fig. 2). The populations of whooping cranes that existed in Louisiana until the 1940's (Lowery 1974), 1 sedentary and the other migratory, are well known.

The situation for Florida is more uncertain. The earliest allusions to whooping cranes in Florida by Audubon and others are suspect because there was and still is a tendency to refer to the sandhill as a "whooping" crane. F. Beverly writing in the late 19th century (Hallock 1875) states, "It is a fact beyond doubt that the whooping crane (*Grus americanus* [sic]) is a resident of Florida. There has been seen for many years upon alligator flats, about twenty miles from Ft. Capron, Indian River a large white bird as tall as a man, which the native Floridians called a stork." He goes on to state that young taken "from a nest" and raised for 6 months were "white from the first" but says "they agreed exactly with the description of whooping cranes." He emphasized the large size and loud voice of these cranes, adding some credence to the accounting. What can be made of the white young taken from a nest? These characters sound very much like a wood stork (*Mycteria americana*) which Beverly does not mention among the species that possibly could be confused with the crane.

Maynard (1881) quotes a Capt. Dummett who assured him that the white whooping crane occurred on the prairies east of the Kissimmee River and Lake Okeechobee, a report later confirmed by others, although Maynard never saw the birds himself. A respected field naturalist active in Florida since 1908, O. E. Baynard stated that the last flock of whooping cranes (14) he saw in Florida was in 1911 near Micanopy, southern Alachua County (Harmon 1954). There is also an account of 2 whooping cranes reported east of the Kissimmee River on 19 January 1936 (Shaffer 1940).

The most intriguing record of a Florida whooping crane comes from B. O. Crichlow, a taxidermist and naturalist, who reportedly shot a whooping crane near St. Marks pond north of St. Augustine, St. Johns County. A report of this incident and a photograph were published (Hallman 1965) but no specific date could be given other than the bird was shot in 1927 or 1928. Indirect contact with Crichlow's son, who was the source for Hallman's article, has produced no clarification of the date but he does remember seeing the fresh, unmounted specimen which adds to the authenticity of this Florida record. Otherwise there is no assurance that the bird B. O. Crichlow had in his collection could not have been from another location and the "whooper" he shot in 1927 or 1928 referred to a sandhill crane. There are other word of mouth records referring to whooping cranes in Florida during the early 1900's--even reports of white cranes on Paynes Prairie. The more these records are researched the harder it is to discount the possibility that whooping cranes did occur and perhaps even were resident in Florida. Undeniably they did occur with some regularity elsewhere in the Southeast.

With the success to date of the foster-parent project being conducted in Idaho, an interesting adaptation of the same technique may be possible in Florida. The whooping crane recovery plan rec-

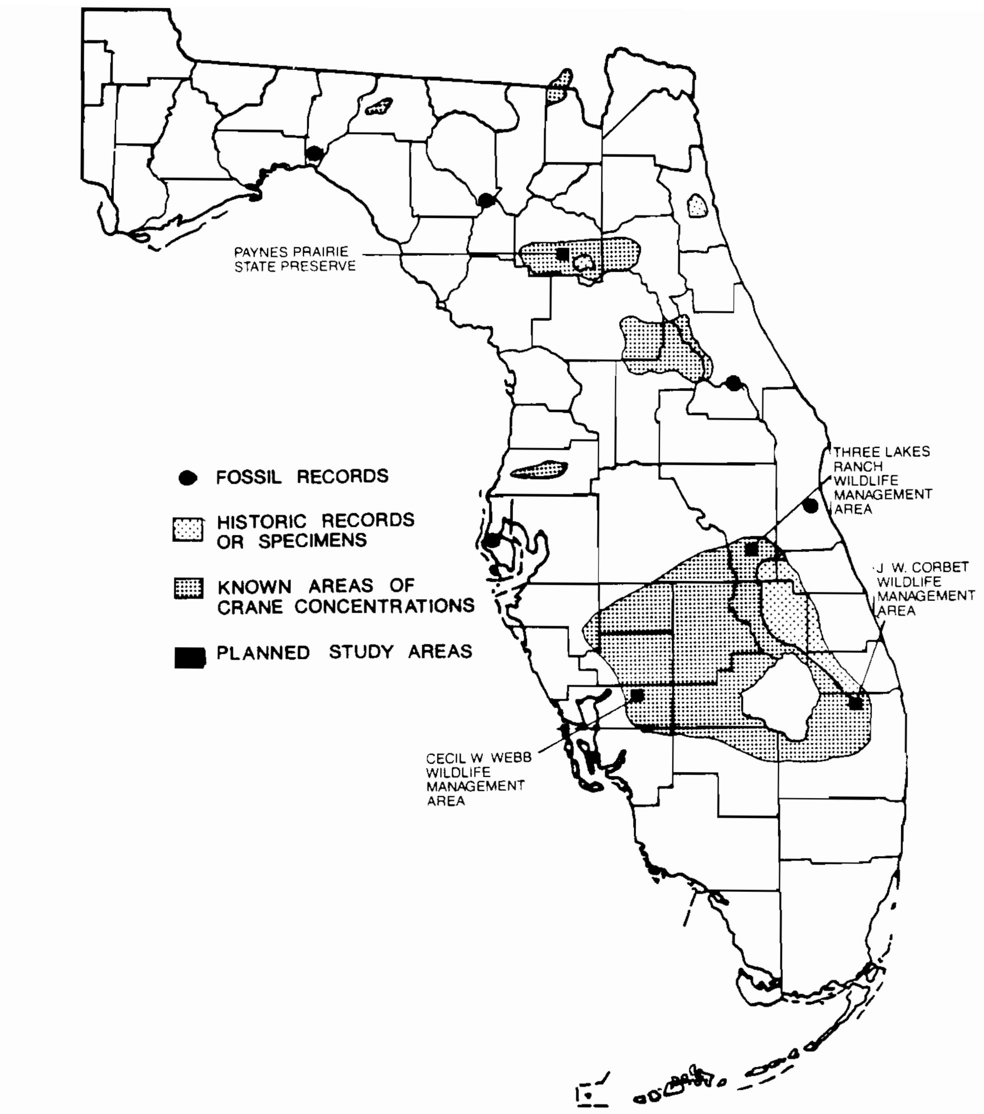

Fig. 1. Whooping crane records and potential release areas in Florida.

commends establishing populations of whooping cranes in addition to the 2 currently in existance. The nonmigratory population of the gulf region no longer exists; consequently, Florida seems to offer a unique location for reestablishing a nonmigratory population of whooping cranes using the resident Florida sandhill as foster-parents.

Young cranes, unlike most birds, remain in the company of their parents for almost a full year. This phase of their life undoubtedly involves learning the acquisition of survival skills. It seems reasonable to assume migration may be a learned behavior. If this assumption is correct then the fostering procedures used in Idaho could be used to produce a resident whooping crane population in Florida. There would be several advantages in using this approach because the young cranes would not be exposed to the stresses associated with migration and they would remain in closer contact with conspecifics during their subadult life, which could improve their chances for successfully pairing and reproducing.

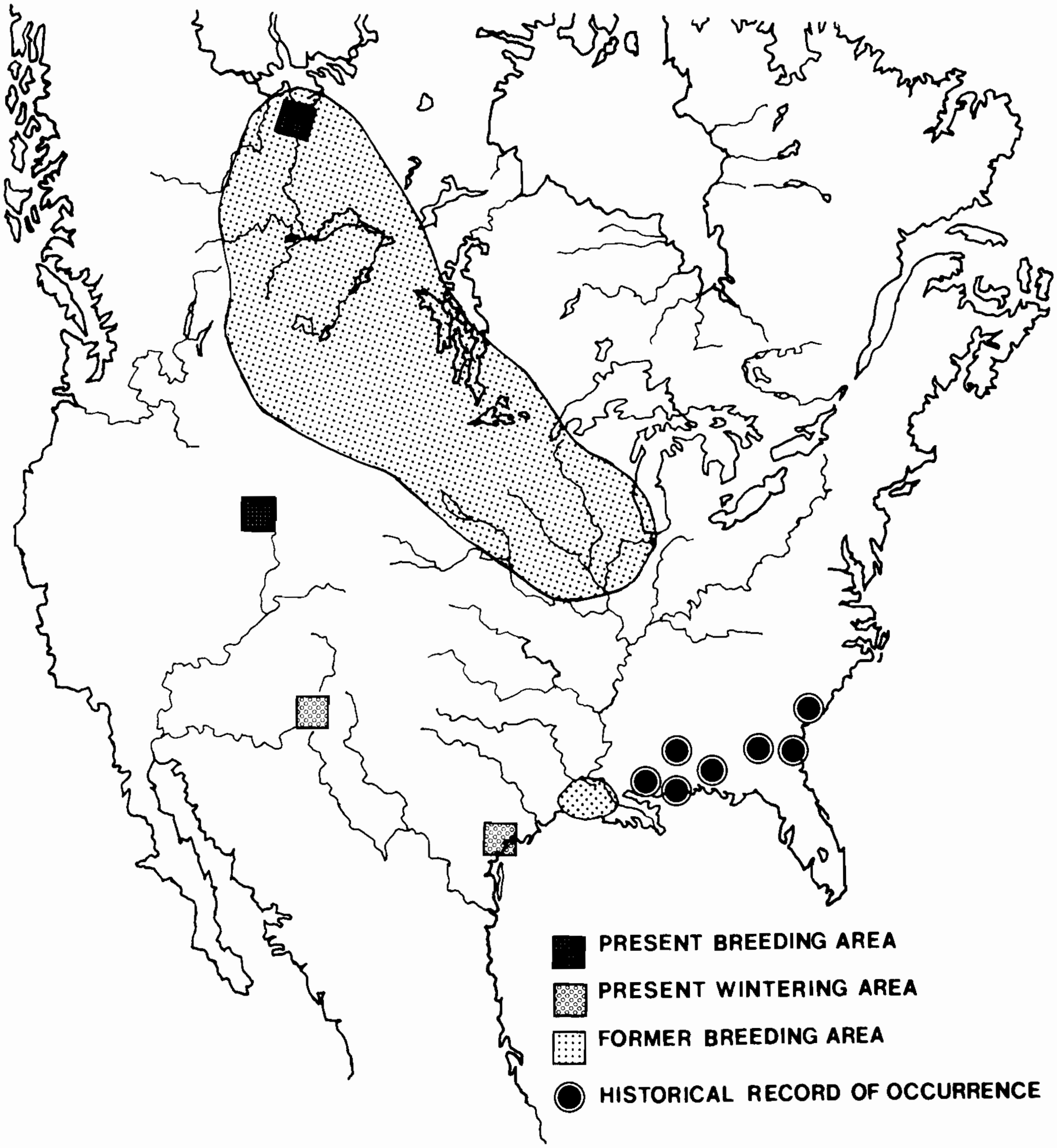

Fig. 2. Past and present range of the whooping crane.

Before beginning any reintroductions of whooping cranes to Florida, it seems advisable to test the feasibility of the procedure using migratory greater sandhill eggs hatched and reared by non-migratory Florida sandhill foster-parents. To do this experiment, we plan to radio-instrument at least 1 member of up to 12 breeding pairs of Florida cranes on Paynes Prairie (Fig. 1) each year for the next 3 years. Eggs from as many as 6 nests will be replaced each year with greater sandhill eggs produced by captive parents at the Patuxent Wildlife Research Center, or elsewhere. Foster-reared young and a sample of normal, control young Florida cranes will be captured, color-marked, and radio-instrumented each year. Their movements will be monitored through at least their 2nd year to determine if the foster young migrate with their genetic cohort or remain in Florida and behave like their foster cohort.

We began marking Florida sandhill cranes on Paynes Prairie during the fall of 1980 and have been studying the movement of 2 radio-instrumented subadults and 1 adult female since January 1981 in order to understand normal movements of Florida sandhill cranes. This knowledge is important to properly evaluate the success of the fostering experiment with greater sandhill crane young.

During this same period we will be looking at potential reintroduction sites in Florida. These areas will be evaluated to locate not only the best sites but also the most suitable foster-parents. Potential reintroduction sites will be evaluated based on total amount of suitable habitat, ownership, present and future management status, access, population of Florida sandhill cranes, and surrounding land use and its suitability for supporting an expanding population of whooping cranes. Surveys will be initiated on the prospective areas to census the populations and locate crane nesting territories. Prospective pairs will be trapped and color-marked to evaluate their suitability as foster-parents. We have located 3 prospective release sites (Fig. 1): Three Lake Ranch, and J. W. Corbett and C. M. Webb Wildlife Management Areas. These 3 areas are state-owned lands which consist of over 20,250 ha of usable crane habitat and possess a good resident population of cranes. We are continuing to look at prospective reintroduction sites. Population and production surveys will begin in fall of 1981 or spring of 1982.

Based on data derived from these preliminary studies, the Florida Game and Fresh Water Fish Commission, the U.S. Fish and Wildlife Service, represented by their Whooping Crane Recovery Team, and the Canadian Wildlife Service will cooperatively decide if they should reintroduce whooping cranes into Florida. If the decision is to proceed, eggs laid by captive whooping cranes at the Patuxent Wildlife Research Center (eggs that are usually laid too early to be used for fostering anywhere else in the country) will be placed in the nests of selected pairs of Florida sandhill cranes perhaps as early as spring 1984.

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DEVELOPMENT OF MINIMUM STREAMFLOW RECOMMENDATIONS FOR MAINTENANCE OF WHOOPING CRANE HABITAT ON THE NIOBRARA RIVER, NEBRASKA

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Abstract: An interdisciplinary study was completed to analyze the potential effects of the Water and Power Resources Service's proposed Norden Dam on whooping crane (*Grus americana*) habitat of the Niobrara River, Nebraska. A primary objective of the study was to develop minimum streamflow recommendations for maintenance of whooping crane habitat downstream of the proposed dam. The study focused on interactions between river hydrology and vegetative succession in maintaining existing habitat conditions. Physical and biological factors which maintain habitat were analyzed to develop minimum streamflow recommendations and to assess future habitat conditions. Recommendations focused on factors which maintain open channel roost habitat and adjacent wetland feeding habitats. Principal controlling factors for maintaining channel width and area were identified as high winter and spring flows combined with ice breakup. Water surface elevation in the river was believed to control groundwater levels in wet meadows adjacent to the river. Analyses of future conditions predicted that whooping crane habitat on the Niobrara River would be reduced as a consequence of clearwater releases from Norden Dam. Such reduction would result from channel degradation which is expected to extend approximately 21 km from the dam in 100 years. Although minimum flow recommendations are believed sufficient to maintain habitat conditions below the degradation reach, their implementation remains problematical because future upstream water uses may reduce river flow below the specified mimimum. Thus, to meet the recommended minimum flow regime, flexibility will have to be developed in the dam's regulation plan.

In recent years, considerable attention has been focused on the relationships between water volume and vegetation successional patterns in riverine systems used by migrant sandhill (*Grus canadensis*) and whooping cranes. Particular attention has been focused on the Platte River, Nebraska, where encroachment of woody vegetation into the river channel has resulted in degradation of roost habitat quality and shifts in historical sandhill crane use patterns. Several studies (Frith 1976, Williams 1978, U.S. Fish and Wildlife Service 1981) have established the linkage between reductions in flow volume on the Platte and reductions in the quality and availability of crane roost habitat. These studies have highlighted the need to consider potential downstream effects when planning proposed water development projects. The requirements of the Endangered Species Act add additional emphasis in situations where whooping crane habitat may potentially be affected.

This paper presents an overview of a study conducted between November 1979 and March 1981 to investigate the potential effects of Water and Power Resources Service's (WPRS) proposed Norden Dam and Reservoir (principal components of the O'Neill Unit) on whooping crane habitats of the Niobrara River, Nebraska. The Niobrara River Whooping Crane Habitat Study (Ellis et al. 1981) was initiated by WPRS following issuance of a U.S. Fish and Wildlife Service (FWS) Biological Opinion (7 September 1979) that the O'Neill Unit, as planned, was likely to jeopardize the continued existence of the whooping crane through destruction or adverse modification of habitat essential to the species. Fish and Wildlife Service projections of adverse habitat modification were based on 2 phenomena: (1) water released from the dam would immediately begin to pick up sediments, resulting in loss of roost habitat through erosion of sandbars and degradation (deepening) of the stream channel, and (2) flow depletions would allow vegetation encroachment into the river channel, resulting in further reductions in roost habitat quality. In its Biological Opinion, FWS offered instream flow recommendations that assumed that future conditions should closely follow existing patterns. FWS stated it lacked information to precisely define needed flow regimes.

WPRS initiated the Niobrara River Whooping Crane Habitat Study in response to the need for additional information to evaluate the potential effects of Norden Dam on whooping crane habitat. The study was not intended to develop, by itself, an operational plan for the reservoir that would allow whooping cranes and Norden Dam to coexist, but to provide information which WPRS and FWS could use to develop additional alternatives for consideration.

The Niobrara River Whooping Crane Habitat Study was funded by WPRS. Work was completed by Environmental Research and Technology, Inc. (ERT) and subcontractors that included River and Hydraulic Engineering Inc. (RHE) and Drs. Gustav Swanson and Roderick Drewien. Many other persons

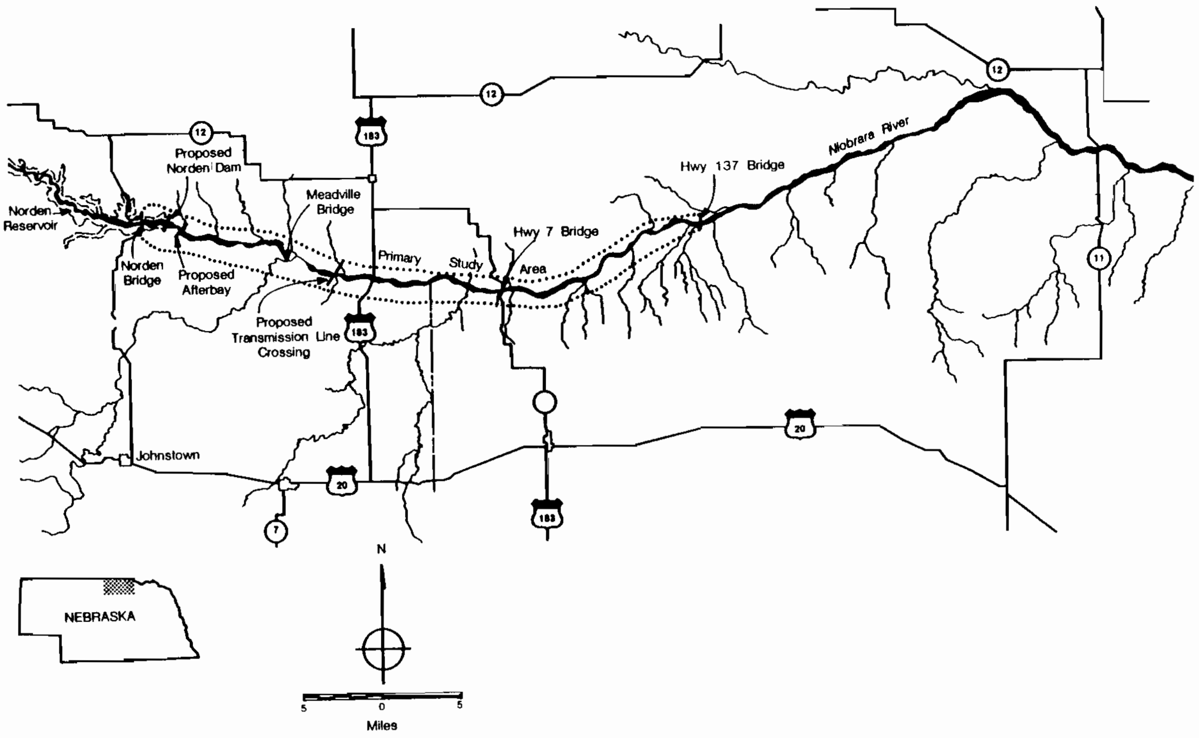

Fig. 1. Regional map of Niobrara River Whooping Crane Habitat Study.

aided the study by providing information or participating in periodic review meetings. The aid of these persons is gratefully acknowledged.

STUDY AREA

The proposed Norden Dam and Reservoir are principal components of WPRS' O'Neill Unit, Lower Niobrara Division, Pick-Sloan Missouri Basin Program, Nebraska. The O'Neill Unit would provide irrigation water to 30,800 ha irrigable near the towns of Springview, Atkinson, and O'Neill, Nebraska (Fig. 1). Norden Dam would be located approximately 28.8 km northwest of Ainsworth, about 2.8 km east of the bridge at Norden. An afterbay structure, designed to control streambed degradation immediately below the dam, would be located about 1.6 km downstream. Norden Reservoir would extend upstream from the dam approximately 30.6 km when full. Total capacity of the reservoir would be 5 X 10^8 m^3 (411,000 acre-feet), 1.5 X 10^8 (125,000) of which would comprise the active conservation pool.

The primary study area included the Niobrara River and adjacent land from the dam site east approximately 64 km to Highway 137 bridge. Within this area, the Niobrara River is characterized by a braided channel which ranges from 61 to 549 m wide as it meanders within a broad valley between bedrock bluffs. There are few vegetated islands or other visual obstructions within the channel and abundant submerged sandbars provide high-quality crane roosting habitat. Both cropland and meadow feeding habitats are available nearby, although neither are abundant. The 56-km reach downstream from the proposed Norden Dam has an established historic record of whooping crane use and is considered an important migration stopover area. A 48-km portion of this area was proposed as Critical Habitat for the species (FWS 1978), but the proposal was withdrawn (FWS 1979) following 1978 amendments to the Endangered Species Act.

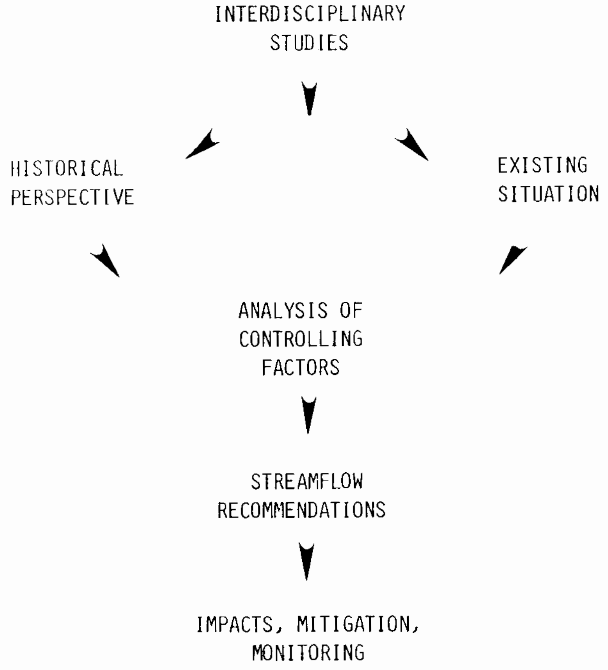

Fig. 2. Conceptual approach to Niobrara River Whooping Crane Habitat Study.

STUDY APPROACH

Design of the Niobrara River Whooping Crane Habitat Study was accomplished jointly by WPRS, ERT, and RHE with input from FWS and several state and private entities which were involved in periodic review meetings. WPRS established the approximate 1-year time schedule, the major objectives, and assumptions related to operational constraints of Norden Dam and projections of future upstream depletions. ERT and RHE developed their approach within the study outline and time frame given by WPRS. General assumptions applied were that the study must be: (1) interdisciplinary, because whooping crane use of the Niobrara River is influenced by many factors including the biology of the species, vegetative characteristics of the river, and hydrologic and geomorphic conditions; (2) based primarily on existing data and aerial photography analysis, given the prescribed time frame; and (3) predictive, within the limitations of available data on whooping crane ecology and the behavior of riverine ecosystems.

A general overview of the study approach is given in Fig. 2. The study team included crane biologists, a plant ecologist, geomorphologists, sedimentologists, hydrologists, modellers, a computer programmer, and support personnel. Major study elements included: review of whooping crane use and evaluation of potential crane habitat; determination of vegetative successional patterns and vegetation-water regime interactions; analysis of historic patterns of channel change and factors which influence channel pattern; development of a sediment transport model for analysis of future channel patterns; preparation of minimum flow recommendations; development of a simulation model of future reservoir releases; and prediction of effects of the proposed Norden Dam. Detailed methods for each analysis are included in the final report (Ellis et al. 1981) along with a description of the interdisciplinary process used to bring the disciplines together to develop minimum streamflow recommendations and analyze impacts.

The following sections present major conclusions and recommendations of the study.

WHOOPING CRANE ECOLOGY

The whooping crane ecology portion of the study influenced other study components because crane needs and habitat requirements determined the focus of hydrologic and vegetation studies. Studies of crane habitat location and quality on the Niobrara were included in the overall study plan to document existing crane use areas and for possible use in making flow management recommendations. Ideally, whooping crane use areas could be identified from past crane activity on the river. However, the 6 confirmed sightings of whooping cranes (Table 1) allow few generalizations. In the absence of more definitive information on actual whooping crane use of the Niobrara, habitat quality evaluations were completed to describe the relative potential for whooping crane use of various river reaches. Dr. Drewien's detailed knowledge and experience with sandhill and whooping cranes were especially helpful in evaluating habitat.

Evaluation of roost habitat quality was completed in successive stages. Characteristics listed by Johnson and Temple (The ecology of migrating whooping cranes. Unpubl. rep. on contract No. 14-16-0009-78-034. U.S. Fish and Wildl. Serv., Off. End. Species, 1980) were qualitatively compared to conditions on the Niobrara, based on ground and aerial reconnaissance and review of aerial photography. Results of this analysis are summarized in Table 2. Several characteristics were then selected from the list for more detailed quantitative analysis, either because perceptible variations in conditions were noted in the qualitative analysis or because the specific characteristic seemed subject to potentially significant change resulting from construction or operation of Norden Dam and Reservoir. Characteristics selected for more detailed evaluation were: availability of feeding habatit, potential for human disturbance, and visibility or openness of the roost habitat.

Table 1. Summary of confirmed whooping crane sightings on the Niobrara River, 1949-spring 1980.[a]

Date	Location	No. of birds	Comments
25 Apr 1957	6.4 km W Meadville	3 unknown age	Three birds observed for 4 hours. Activities included feeding in shallow waters near sandbars, loafing on sandbars, and short flights in response to disturbance. When 1st observed they used an area estimated at 0.8 km wide, but were also observed within 69 m of bank. Food items taken unknown, but observer speculated minnows were caught.
19 and 20 Oct 1965	N Bassett, Rock County	3 unknown age	Details of sighting unknown.
3 Oct 1969	0.8 km W of Carns (S24 T 32N R19W)	2 adults[b]	Birds seen in flight over Niobrara River.
29 Oct 1974- 1 Nov 1974	About 1.6-2.4 km E Hwy. 183 (S19 T32N R19W)	8 adults	Birds used bare sandbar and shallow water areas near center of wide river channel (183-366 m) foraging in open water, and resting on sandbar or in shallow water just off of a sandbar. During observation period, birds stayed in same general vicinity and did not leave to feed.
3 Nov 1977	NW Bassett on Niobrara River (SE 1/4 NE 1/4 S22 T32N R20W)	3 adults 1 immature	Birds loafing on bare sandbar near center of wide river channel. Water depth estimated at 15 cm. Not observed feeding, but small grainfields within 4.8 km. Subirrigated wet meadows available to north. Minnows and crayfish assumed present in river.
30 Oct 1979	0.4 km upstream of Cornell Dam, near Valentine	6 adults 1 immature	Birds loafing on bare sandbar in river.

[a] Based on material in Johnson and Temple (1980), Whooping Crane Recovery Team (1980), and unpublished sight records.

[b] Reported as 1 bird in Whooping Crane Recovery Team (1980) and as 2 birds in Johnson and Temple (1980), based on letter from observer.

Feeding habitat evaluations were based on habitat descriptions in the literature and focused on identification of potential feeding areas which could be influenced by changes in streamflow. Feeding habitats (e.g., corn and wheat fields, the Niobrara River channel, herbaceous wetlands, and subirrigated meadows) were mapped and their area calculated for use in future monitoring. In general, meadow areas are found in the eastern part of the study area, and croplands in the west. No portion of the study area had large areas of cropland or meadow in close proximity. Subjective evaluation of the area led us to conclude that feeding habitat for migrant sandhill and whooping cranes is limited on the Niobrara, in comparison to other important use areas. Adequate feeding areas appeared to be present for cranes stopping overnight or for a few days.

Human disturbance potential was rated by evaluating proximity of potential disturbance features such as roads or houses. A few areas are near frequent sources of human activity, primarily bridge

Table 2. Summary of qualitative evaluation of whooping crane roost habitat on the Niobrara River.

Evaluation characteristic[a]	Summary of conditions[b]
1. Shallow water	Shallow water areas appear to be abundant throughout the study area, but this varies with discharge and varies laterally in a river cross section. Analyses were made of changes in water depth over sandbars with changes in river flow.
2. Good horizontal visibility	Horizontal visibility within the river channel is excellent throughout the study area. The river channel is wide and there are very few vegetated islands which interrupt visibility within the channel. High banks and tall, dense streamside vegetation do occur, so horizontal visibility is limited by channel width. Analyses were made to document variations in this characteristic.
3. Good overhead visibility	This characteristic depends on channel width because high banks and tall vegetation are common. Additional analyses were made of channel width.
4. Devoid of dense emergent or floating vegetation at the roost	Floating and emergent vegetation were not detected anywhere. Emergent vegetation does occur at the channel edge in some areas.
5. Devoid of vegetation on the river bottom	The Niobrara River bottom material shifts constantly. It is very unlikely that submerged aquatic vegetation occurs within the river channel.
6. Bottom composed of finely divided material, usually sand	The river bottom is very fine sand.
7. Isolated from human development	Most portions of the study area are sparsely populated and lack sources of human disturbance; this varies because a few houses do occur in the river valley and dirt roads follow the river in some locations. Areas were documented where the risk of human disturbance is comparatively high.
8. Relatively close to feeding site	The river channel is available as feeding habitat throughout the study area. Croplands are primarily restricted to the western two-thirds and nonchannel wetlands occur only in the eastern third of the study area. Availability of feeding habitat was quantified.
9. Slow flowing water	Flow velocity in the Niobrara depends on discharge and lateral position in the river channel. At high flows, the deep thalweg carries much of the total flow volume at high velocity. Most of the river channel, however, has shallow water moving at low velocity.
10. Sandbars present with gradual slope from water, minimal topographic relief, low banks, and no low vegetation or unvegetated.	Sandbar areas are abundant. Most are submerged and appear to meet the described characteristics. Few sandbars were noted with vegetation.

[a] Characteristics noted are paraphrased from Johnson and Temple (1980) but are consistent with other literature sources.

[b] Subjective evaluation based on April 1980 field reconnaissance and review of April 1980 aerial photography.

crossings, but most of the study area is isolated from sources of human disturbance.

Visibility characteristics or the "openness" of roost habitat was considered a key evaluation factor because future encroachment by vegetation, induced by changes in flow regime, may cause marked changes in habitat suitability and use (Frith 1976, Lewis 1976). In the study area, visibility characteristics are generally excellent because the river is wide and the view is unobstructed. Variable conditions do occur; some reaches are affected by high banks, encroachment of vegetation from the bank, or the growth of vegetation on sandbars or islands in the channel. A general trend of increased openness occurs from west to east as river width increases.

During reconnaissance activities in April 1980 these variations in openness of the river channel were noted as 1 of the few factors affecting relative habitat quality in the study area. Preliminary evaluations of roost quality were made in the field, with the understanding that adjustments in boundaries and ratings would be made using measurements from aerial photography. Preliminary ratings were strictly qualitative and were defined as follows:

1. *Unacceptable* - Areas that do not provide roost habitat. Very narrow river reaches with a deep channel and no sandbars; bordered by tall vegetation and high banks.

2. *Low* - Areas that could be used as roost sites, but probably would not be used because better habitat exists nearby. Generally narrow reaches at bends, reaches with vegetated islands in channel.

3. *Medium* - Generally provide good quality roost sites, but are not the really prime areas. River width is less than in other areas and surrounding terrain or vegetation limits visibility.

4. *High* - Prime areas. They have abundant sandbars in wide areas of the river. Surrounding topography and river banks are generally low and level. Streamside vegetation is generally quite low.

To quantify the "openness" factor within the study area, measurements of unobstructed channel width were taken at 186 data points covering the entire 64-km reach. Unobstructed channel width was defined as the bank-to-bank channel width, if islands were absent from the channel, and bank-to-island, or island-to-island channel width (whichever was greater) when vegetated islands were present. A simple frequency analysis of unobstructed channel width measurements was completed for each subjective rating category. There was overlap in the categories because reach boundaries drawn in the field were rather broad, but ratings generally fit ranges as follows: U-L - <152 m, M - 152-274 m, and H - >274 m. These ranges were used as criteria for more accurately defining boundaries between reaches of different quality. Sixty-four distinct reaches were identified and mapped. Table 3 summarizes the availability of each rating category in linear extent over the 64-km area.

Table 3. Summary of roost quality ratings for Niobrara River study area.

	Linear extent of quality rating classes (km)			
Roost quality[a]	Norden to Meadville	Meadville to Hwy 7	Hwy 7 to Hwy 137	Entire
High	3.92	8.66	8.62	21.20
Medium	9.44	7.94	11.90	29.28
Low	3.36	4.56	3.76	11.68
Unacceptable	0.0	1.76	0.0	1.76
Totals	16.72	22.92	24.28	63.92

[a] Ratings were based on relative quality of roost habitat in 64 reaches in the study area. Unobstructed channel width was considered a key parameter and ratings generally fit ranges as follows: U - Unacceptable as roost habitat due to lack of sandbars, not channel width; L - 0-152 m width; M - 152-274 m width; and H - 274 m and wider.

Unobstructed channel width data and habitat quality rating categories developed for the Niobrara River were compared to similar measurements or ratings in the literature. Measurements were taken on 4 reaches of the Platte River, Nebraska, which had been rated in 1971 by Frith (1974, 1976) in terms of the relative degree of vegetative encroachment. Although the literature base was sparse, general conclusions were that sandhill and whooping cranes generally prefer roosts with unobstructed channel widths in the range of 152 to 183 m or wider. This range closely agrees with the conclusion, reached during field reconnaissance activities, that High and Medium rated areas would be those most likely to be used as whooping crane roosts.

CHANNEL PATTERN

RHE's study team completed a detailed analysis of geomorphic and hydrologic conditions of the Niobrara River. Their review concentrated on factors which influence channel pattern, especially those which act to maintain the wide braided conditions ideal for crane roosts. Investigation of the channel pattern in the study area relied on aerial photographs taken in 1938, 1954, 1968, and 1980 (2 sets taken in April and September) and 3 river cross-section surveys conducted respectively in June and August 1979 and April 1980. The discharges at the gaging station near Norden were 28.3 m^3/sec and 13.2 m^3/sec in April and September, respectively, when the 1980 aerial photographs were taken. These 2 sets of aerial photographs represent high and low flow situations of the Niobrara River in the study reach. RHE identified a number of factors which act in combination to produce existing conditions. The following sections briefly summarize findings which were most useful in development of minimum streamflow recommendations.

Thalweg Behavior

The Niobrara River is a braided stream in the study reach. By comparing aerial photographs taken in April and September 1980, it was found that a meandering thalweg (the deepest part of a river channel) was formed along the entire study reach in April. A thalweg is usually sinuous and carries a large proportion of total flow at higher velocity than the rest of the channel. The thalweg in the study area averaged 61 to 92 m wide, 0.9 to 1.5 m deep, and carried 47 to 84% of total flow.

This meandering thalweg had almost completely disappeared in September. By mid-December 1980 the thalweg channel pattern had reappeared in a high-flow situation. These observations indicate that part of the flow concentrates within a rather narrow channel during high flows. In contrast, the flow is much more uniform and covers most of the river cross-section during low flows. By comparing all 5 sets of aerial photographs, it was further determined that the thalweg shifted laterally within the stream channel during the 1938 to 1980 observation period. In addition to the evidence obtained from the aerial photographs and field observations, careful comparisons were made between August 1979 and April 1980 cross-sectional measurements. The flow spread to cover the whole cross section in August 1979 (low flow) and concentrated in a rather narrow width in April 1980 (high flow).

The lateral spreading of flow in the low-flow situation results in a rather small range of variation of water surface elevation with respect to river discharges. Based on the cross-sectional surveys in June and August 1979 and April 1980, water surface elevation rose only 20.3 cm when the flow discharge increased about 16.8 m^3/sec at a crosssection 59.2 km downstream from the Norden Dam site. The rate of change of water surface elevation was approximately 0.08 m^3/sec.

The shifting of the meandering thalweg at the high-flow condition and the lateral spreading of flow at the low-flow condition, provide the river with a mechanism to maintain a wide channel. This mechanism is especially important for maintaining suitable whooping crane habitat after the closure of the proposed Norden Dam.

Channel Degradation

Channel degradation (deepening) in the study reach was revealed from 2 lines of evidence. Degradation at a cross section about 1.6 km downstream of the gaging station near Norden was confirmed by WPRS and estimated at 0.9 m based on water surface elevations measured in 1957 and 1980. Also, a continuous downward shifting of the stage-discharge rating curve at the gaging station near Norden was noted between 1960 and 1979, except during an abnormal period of 1962-1966. Washout and reconstruction of the county bridge at the site of the gaging station caused the river bed to aggrade and then degrade during 1962 and 1966 and account for the abnormality. The degradation rate was estimated at about 20 cm per year.

Surface water studies revealed that the Niobrara River in the study area has been affected by depletions due to upstream water resource developments: the Mirage Flats Project and the Ainsworth Unit. The Mirage Flats project diverted water from the Niobrara River beginning in 1946. The Ainsworth Unit, which includes Merritt Reservoir on the Snake River, began operation in 1964 and resulted in a decrease of average annual flow from 26.9 to 22.7 m^3/sec.

To analyze the possibility that the operation of Merritt Reservoir caused the observed channel degradation, we examined the stage-discharge relation at the gaging station near Sparks, 32.8 km upstream from Norden. Although the stages fluctuated during the 20 years, there was not enough evidence to show that the stage in general was decreasing or increasing. In short, no degradation was found at Sparks gaging station.

It is also possible that reductions in river flow caused by Merritt Reservoir storage, or other factors, could have resulted in channel degradation. Analysis of controlling processes indicated that winter and early spring high flows, combined with ice, play the most important role in maintaining river channel shape. To analyze the possibility that upstream water uses significantly reduced flows during this critical period, February and March flows from the period of record were plotted to determine if a downward trend existed. The analysis was inconclusive. Consequently, the reason for the observed degradation remains unclear. Possible explanations include man-induced depletions and natural fluctuations in river flows and channel pattern.

Width Change

Changes in channel width were investigated using aerial photographs taken in 1938, 1954, 1968, and September 1980. The study reach was divided into 159 sections, each about 0.4 km apart, and the width was measured between the permanent edges of the channel at each section. The results indicated that the channel width increased from 1938 through 1954 and started to decrease between 1954 and 1980. The decrease was found to be greater from 1968 to 1980 than 1954 to 1968. Furthermore, the decrease in channel width was found to be greater near the Norden Dam site than farther downstream.

While investigating reasons for this channel width change, it was noted that channel degradation occurred during the same period as decrease of channel width. Channel degradation offers a reasonable mechanism for explaining channel width change.

- Channel bed elevation changes over only a portion of the river cross section.
- This drop in channel bed elevation leaves areas at slightly higher elevations on the edge of the channel.
- As the difference in elevation increases, outlying areas are not subject to the overall pattern of thalweg shifting or ice scouring.
- Outlying, higher elevation areas are invaded by vegetation and are stabilized, decreasing overall channel width.

Based on this postulated mechanism it was concluded that changes in channel width in the Norden-Meadville reach since 1954 were due to channel degradation. The reasons for the overall pattern of widening and narrowing, however, remain unclear as previously noted. Because of the postulated relationship between channel degradation and channel width reduction, the 2 phenomena were quantitatively analyzed for calibration of the sediment transport model. During impact assessment, observed channel width changes were used as the basis for adjusting channel widths when predicting the extent of degradation caused by the dam.

Sandbar Distribution

The distribution of river sandbar area in relation to submerged depth is an important factor in evaluating whooping crane habitat. Aerial photographs taken in April and September 1980 were analyzed to study how sandbar areas vary with the flow condition at different submergence depths. The overall study reach was subdivided into 10 reaches, each about 6.4 km long. Seventeen cross-sectional profiles surveyed by WPRS in April 1980 were used to calibrate the colors of the aerial photographs to the water depths at the cross sections. The submerged depths were divided into 5 groups: unsubmerged, 0-15.4 cm depth, 15.4-30.7 cm depth, 30.7-46.1 cm depth, and depth greater than 46.1 cm. The area of each individual sandbar belonging to 1 of the 5 groups was recorded for each section. Based on this information, the total area and the sandbar size distribution were calculated for each submergence depth class. Similar procedures were performed using the aerial photographs taken in September 1980, to determine sandbar distributions at low flow, except that the colors of the photographs were calibrated by using the profiles of some stable channel cross sections from those surveyed in April 1980.

These data were aggregated to better reflect crane roost preferences; 0-30.7 cm was thought to span the range of preferred depths, and 0-46.1 cm was considered usable habitat. Results of the analysis showed an increase in both preferred and total available habitat as flow decreased from about 28.3 to 13.2 m^3/sec. This was attributed to a decrease in deep water areas as the thalweg filled in and river flow spread over the entire channel.

Ice Effects

Although very little information is available to provide a quantitative analysis of the effects of ice on river morphology, it is generally agreed that the formation of ice will increase flow resistance, reduce flow velocity, and thus increase the flow depth for the same river discharge. In braided streams, the increase in depth enhances the lateral spreading of flow. The formation of ice and the breakup of ice in a shallow river will also erode sandbars and banks, and mechanically remove vegetative material.

Quantitative investigations of the effects of ice formation and breakup were not within the scope of this study. Field reconnaissance was conducted in December 1979, February 1980, and December 1980 to qualitatively investigate ice-related phenomena. Photographs of the river channel were also taken weekly from late December through March to document ice buildup and breakup near Meadville. Based on these efforts and discussions with local residents, it was noted that: (1) ice forms annually on the Niobrara, usually by December; (2) ice formation may occur several times during a winter, as weather conditions vary; (3) the major ice breakup period is usually in March, coinciding with high flows; (4) major ice jams periodically occur in the system and these significantly raise the river level; (5) freeze-thaw patterns and ice breakup apparently create very unstable conditions in the channel; and (6) ice and high flow combinations appear to have a high potential for increasing the mechanical scouring force of the river.

ENCROACHMENT OF VEGETATION

Encroachment of vegetation was analyzed by comparing changes in vegetative community area between 1954 and 1980. Aerial photography for these 2 periods (and an intermediate period of 1968) was interpreted, and areas of vegetation cover types calculated (Table 4). The river was divided into 3 reaches, corresponding to past FWS aerial wildlife surveys. The major trend apparent from this analysis was a reduction in open channel area in both the Norden-Meadville and Meadville - Highway 7 reaches, and an increase in the low shrub category in the same reaches. Channel area remained essentially constant in the Highway 7 - Highway 137 reach. Low shrub area increased in this reach, but the increase was nearly balanced by reductions in the tall shrub and riparian woodland categories. Changes in land-use categories were attributed to changes in use between photography years. For example, reduction in cropland between 1954 and 1968 presumably resulted from conversion of this land into some other use (e.g., dry pasture, dry hayland).

Analysis of areas where vegetation increased or decreased showed that increases occurred generally above constrictions in the river, above and below major bends, and downstream from tributaries. The overall pattern was encroachment from the shore. Island formation occurred but extension of the bank into the channel was the more important change. These data suggested that the river, at least in the upper portions of the study area, is less effective in reducing vegetation establishment and growth on the channel margins. Areas where encroachment decreased were generally small in size, and frequently occurred where the river had cut toward a bank.

RIPARIAN VEGETATION-RIVER INTERACTIONS

The establishment and growth of shrubs and trees on banks and sandbars affects available whooping crane roosting habitat on the Niobrara River. The following section discusses the ecological and physiological characteristics of the 3 major successional phases (herbaceous, shrub, shrub-tree, Table 5) in relation to major environmental factors that control the extent and rate of successional change within each phase in the Niobrara system.

Table 4. Area (ha) comparisons of vegetation and land-use types for 3 reaches of the Niobrara River.

	Norden-Meadville			Meadville-Hwy 7			Hwy 7-Hwy 137		
Area	1954	1968	1980	1954	1968	1980	1954	1968	1980
Subirrigated meadow - pasture	21.6	36.0	33.2	34.0	16.0	15.2	163.2	96.0	105.2
Subirrigated meadow - hayed				52.0	29.6	30.8	412.0	421.2	438.8
Dryland hayland				203.6	96.4	32.0	104.0	83.6	99.6
Dryland pasture	23.2	26.4	58.8	106.4	267.6	320.0	32.8	33.6	30.0
Dry grassland	71.6	88.8	80.4	26.0	19.2	1.2	36.8	45.6	5.6
Cropland - grains	34.8	40.4	52.4	126.0	28.8	122.4	6.0		8.0
Low shrub	64.0	60.8	131.6	78.8	68.0	138.8	26.4	26.8	78.0
Tall shrub	45.6	34.0	10.4	22.8	63.2	62.0	42.4	33.6	34.4
Riparian woodland	242.4	246.8	269.6	479.6	550.8	510.4	465.2	536.0	469.6
Wetland - shrub		2.4	6.8	3.2	1.6	16.4	16.8	2.0	20.4
Wetland - herbaceous					4.4	3.2	13.2	26.4	28.8
Open channel	542.0	509.6	402.0	732.4	719.2	612.4	705.2	719.2	705.6
Total	1,045.2	1,045.2	1,045.2	1,864.8	1,864.8	1,864.8	2,024.0	2,024.0	2,024.0

Herbaceous-Open Sandbar

Factors that limit the establishment and early growth of woody species which could potentially increase in dominance, and encroach upon open sandbar habitat, are of critical concern to the maintenance of whooping crane habitat. An understanding is required of the adaptations of these woody riparian species to their habitat. A summary of the literature on germination, establishment, and flood tolerance of cottonwood and willow in the United States was prepared and the following discussion is abstracted from that review.

Flowering and seed dispersal in cottonwood and willow usually occurs from late spring (May) through mid-summer (July). Along the Niobrara River in early June, 1980, sandbar willow, peachleaf willow, and most cottonwoods had shed seeds. Seeds of indigo bush were still green. Cottonwood and willow seeds, which consist of long fine hairs attached to the seed, are wind-dispersed. Individual seeds are very small, and enormous numbers are released.

For optimum germination, most cottonwood and willow species require a moist, bare substrate in full sunlight. The viability of these seeds is very short. In general, if the seed does not land on a favorable germination site within 5 days after dispersal, it is highly likely that the seed will die. Exposed sandbars in the Niobrara River channel offer ideal germination sites for these woody species.

Seedlings rapidly develop an extensive root system. Eastern cottonwood may develop a 30-45 cm tap root and 5-10 lateral shoots 0.6 m long during the 1st growing season (Ware and Penfound 1949). Seedlings may grow extremely rapidly in height under optimum conditions, sometimes exceeding 1 m during the 1st growing season. Field observations on the Niobrara indicated that in the absence of disturbance, 1st-year willow seedlings may attain a height of 0.1-0.2 m; 2nd-year seedlings approximately 0.5-0.8 m; and 3rd-year seedlings up to 1.5 m.

Most willow and cottonwood seedlings are highly tolerant of flooding. Seedlings can easily withstand up to 30 days of inundation. Cottonwood seedlings appear to be less tolerant than willow

Table 5. Vegetative succession on Niobrara River shoreline and islands.

Years (stem age)	Woody species height (m)	Community	Species composition (dominants)
0	0	Bare sandbar	--
1	0.1-0.2	Herbaceous	Ragweed (*Ambrosia* spp.), Spikerush (*Eleocharis* sp.), Kentucky bluegrass (*Poa pratensis*)
2-5	0.1-1.0	Low shrub (early phase)	Sandbar willow (*Salix interior*), Peachleaf willow (*Salix amygdaloides*)
5-10	1.0-2.5	Low shrub (late phase)	Sandbar willow, Peachleaf willow, Indigo bush (*Amorpha* spp.), Kentucky bluegrass
10-15	Shrub: 1.0-3.0 Tree: 2.0-5.0	Tall shrub	Peachleaf willow, Red osier dogwood (*Cornus stolonifera*), Current (*Ribes* spp.), Snowberry (*Symphoricarpos* spp.), Cottonwood (*Salix* sp.), Green ash (*Fraxinus pennsylvanica*), Eastern juniper (*Juniperus virginiana*)
15-25	Shrub: 2.0-3.0 Tree: 6.0-10.0	Riparian Woodland	Eastern cottonwood (*Populus deltoides*), Green ash, Eastern juniper, Red-osier dogwood
25-40	Shrub: 2.0-3.0 Tree: 10.0-15.0	Riparian Woodland	Green ash, Basswood (*Tilia* spp.), Eastern cottonwood, Eastern juniper, Red-osier dogwood

seedlings, although tolerance may vary with ecotype. Seedlings and mature trees appear to have anaerobic metabolic pathways which enable the plant to survive in low-oxygen environments. Very sparse populations of cottonwood and willow seedlings observed over most of the sandbar habitats in the Niobrara River indicated that the scouring action of the river was very effective in limiting seedling establishment and removing most seedlings that do become established.

Shrub

The transition from low herbaceous-dominated sites to shrub-dominated sites is of primary concern in assessing riparian vegetation stability and the potential impacts of dam construction. The river-vegetation interaction was examined by measuring the elevation of 20 sampling points and then relating these sample point elevations to river surface elevations at different discharges, to determine the possible effects of high and low flows on shrub communities. Four major parameters (shrub canopy cover, stem density, species composition, and species diversity [number/sample]) were ordinated against elevation to look at possible trends in response to elevation above the water surface.

Ordination of shrub stem density against elevation indicated that stem density peaks at approximately 0.6 m above the average water surface elevation, and then declines as shrub communities mature under tree canopies present on tree-dominated sites. Shrub cover increased with elevation. Number of woody species sampled increased from an average of approximately 3 to approximately 10 between 0.9 and 1.2 m. This change was interpreted as a transition between sites chronically impacted by high flows, and those relatively unaffected by high flows. Flood-tolerant species (peachleaf willow, sandbar willow, indigo bush) dominate the low shrub phase between 0.3 and 1 m above the average water surface elevation; these species decrease in importance on sites sampled more than 1 m above the river water surface. Based on height criteria used in classifying vegetation samples into vegetation types, density and height of shrub communities often exceed 1 stem/m^2 and 1 m in average height at an elevation less than 0.3 m above the water surface elevation associated with a flow of 33.9 m^3/sec at the Norden gauge.

A comparison of shrub height with stem age indicated that stem height for several of the dominant riparian species ranges between 1 and 2 m by approximately 5 to 8 years. Willow stands next to the channel are apparently even-aged, based on the uniformity in stem height over a large area. This observation suggested that a high flow even probably exerted a widespread and relatively uniform suppression effect on shrub communities. Livestock browsing appeared insufficient as a controlling factor because more heterogeneity in shrub height would be expected between individuals of different species, and between individuals of the same species.

Based on the data discussed above, it is concluded that winter ice combined with high flows provides the most reasonable explanation for the observed woody species distribution pattern. The importance of winter ice and high flows in controlling the growth of riparian shrub communities previously has been suggested by several authors (Johnson 1950, Lindsey et al. 1961, Wilson 1970). However, there is little documentation in the literature which provides actual measurements of ice effects on vegetation. This lack of documentation is attributed to the difficulty of sampling, difficulty in making generalizations about observed interactions in the extremely complex ice-river channel environment, and the periodicity in important ice buildup events that may span several years. The following discussion of the ice and high flow controlling factor is based on (1) vegetation sampling data, and (2) qualitative observations on the Niobrara River during the winter of 1979-1980. The reasoning used to arrive at an assessment of the relative importance of this factor is as follows:

- Flood tolerant woody species with stems 5 years or less in age are found at elevations from 0-0.6 m above the water surface elevation; stems 10 years or less are found at elevations of 0.6-1 m above the water surface elevation. These data indicate that shrub communities containing young stems dominate the Niobrara River shorelines. Most of these young stems arise from massive, mature root systems that form a network below the soil surface. These observations taken together (young stems, old root systems) suggest that these root systems resprout after disturbance, and that disturbance events are fairly frequent.

- Hydrologic data indicate that river water surface elevation increases very little with large increases in river discharge. An increase from 25.5 to 42.5 m^3/sec typically raises the water surface elevation 15 cm or less. This relationship is explained by the extremely large river channel area, and very shallow water depths that predominate.

- The small increase in water surface elevation resulting from high flows is insufficient to affect the majority of the shoreline shrub communities. Conditions that could raise the water surface 0.6 m or more could occur only if the river were partially dammed by ice during high flows. Evidence exists for ice jams for various river segments (R. Andrews pers. comm., hydrologist, Water and Power Resources Service, 1980). High water alone is generally insufficient to severely damage highly tolerant willow stems. Mechanical injury from ice is more plausible as a controlling factor for significantly reducing shrub height along shorelines.

- The river appears to be effective in periodically removing root systems of woody species rooted along river shorelines. It was assumed that considerable mechanical force is required to excavate, break up, and remove these woody root systems from the channel. The following combination of factors would be most effective in accomplishing this process:

  --Lateral movement of the channel (thalweg) which would permit undercutting and abrasion of root systems.

  --Abrasion of stems by ice blocks.

  --Frequent freeze-thaw cycles that would allow the river flexibility in lateral movement, and would result in a heterogeneous pattern of sediment deposition and transport, and maximum ice movement and jamming.

Shrub and tree seedlings were very scarce on sandbars, thus indicating that the predominant mode of reproduction is vegetative. The river is effective in preventing establishment of seedlings during the growing season, and effective in removing young stems during the winter and early spring high flows.

Shrub-Tree

The mature riparian woodland communities represent the most stable elements in the Niobrara River riparian system. Soil-binding by the tree root systems and understory woody species resists erosion by the river. These communities grow on terrain high enough that they are affected by only the most extreme high water events. Examination of historical changes in vegetative community distribution indicates that riparian woodland communities are vulnerable to major channel shifts, particularly on the outside of channel bends. Analysis of aerial photography between 1954 and 1980 showed that riparian woodlands have been undercut and removed by river action. The presence of mature riparian woodland on small islands in the channel also suggests that the river will occasionally cut behind shoreline riparian woodlands and isolate these stands as islands.

MINIMUM STREAMFLOW RECOMMENDATIONS

A principal objective of the Niobrara River Whooping Crane Habitat Study was to develop minimum streamflow recommendations for maintenance of whooping crane roosting and feeding habitat below the proposed Norden Dam. Maintenance was defined as insurance that the principal controlling factors would continue to operate in the Niobrara River system for magnitudes and durations sufficient to keep the area and quality of key whooping crane habitat components (roost sites and feeding areas) at levels approximately the same as those that existed in 1980. Emphasis was placed on maintenance of roost habitat because it is most directly affected by changes in streamflow.

Analysis of the historical record indicates that there have been both long-term and short-term fluctuations in important parameters (channel width, channel area). The objective of prescribing minimum flows in a highly dynamic system such as the Niobrara River was to maintain equilibrium conditions in which habitat losses are balanced by habitat gains. A destabilizing factor (channel degradation) was found to be presently operating within the study reach. The prescribed flows would not stop this ongoing process, but should, to the best of our understanding, insure that areas that are at or near equilibrium over the period of record (1938-1980) should not change, on the average, from 1980 conditions.

In the minimum streamflow analysis, emphasis was placed on limiting the extent of channel degradation due to clearwater releases, maintaining existing channel forming and scouring phenomena, preventing woody seedling establishment, and providing shallowly submerged sandbar areas for crane roosts. Minimum streamflow recommendations (Table 6) represent ERT's best judgment of conditions needed to maintain habitat; however, the behavior of the Niobrara River is not completely understood. Thus, minimum streamflow recommendations cannot eliminate all risks of habitat degradation, and habitat monitoring is considered a critical part of any plan to implement the recommended minimum streamflow regime.

Channel Degradation

Degradation was estimated to be the process that could and probably would result in a rapid deterioration in crane roosting habitat in a reach immediately downstream from the afterbay. Based on observations in the reach below Spencer Dam (east of the study area) and historical trends in reaches where degradation is known to be occurring, channel widths reduce and shoreline vegetation rapidly invades into degraded channels. In the example of Spencer Dam, the downstream degradation reach is a narrow, single-threaded stream for several kilometers.

The principal issue considered with respect to degradation was whether the degradation reach and the degradation depth could be significantly reduced by releasing a constant flow rate over the entire year instead of varying flow rates. This question was explored by analyzing the degradation caused by both varying and constant flows in the mathematical sediment transport model. It was found that the degradation depth for a mean annual flow of 12.3 m^3/sec would be approximately 15% more (total volume) under anticipated varying flows than with constant flow releases, but that the degradation reach would be extended only 0.37 km farther. Based on this result, it was decided that releasing a constant flow rate to reduce the degradation was not as important as providing varying winter flows to maintain proper channel patterns downstream of the degradation reach.

Table 6. Summary of recommended minimum flow regimes to maintain whooping crane habitat on the Niobrara River.

Month	Minimum flow (m^3/sec)	Rationale
January	11.3	Ice formation period. Recommended flow is sufficient to cover river channel with shallow water, allowing extensive ice coverage. Decreased flows, in comparison to historical record, indicate greater probability of ice formation.
February	11.3	Same as January.
1-25 March	2813	Period of ice breakup. Important period for shifting of thalweg and scouring of river channel. Relationships between scouring "force," river flow, and ice coverage are not well understood, so approach is to maintain historic conditions during this critical period.
29-31 March	14.2	Crane use period. Recommended flow increases available submerged sandbar habitat in comparison to historic flows. Approximately 78% of open channel is available as crane habitat (0-46.2 cm submergence class).
April	14.2	Same as last week of March.
May	14.2	First week is end of crane use period. Remainder of month is seed shed and seed germination period. Recommended flow is sufficient to cover about 93% of open channel with water. This assures that there will be a minimum area of unsubmerged sandbar on which seeds could germinate and that germination conditions should not differ significantly from the existing situation.
1-15 June	14.2	Same as May.
16-30 June	2.8	End of seed germination period. Flows reduced to arbitrary level of 2.8 m^3/sec. This flow is sufficient to maintain overall braided character of stream. Aquatic habitats should be maintained.
July	2.8	Same as end of June.
August	2.8	Same as July.
1-15 September	2.8	Same as July.
15-30 September	14.2	Crane use period. Recommended flow increases availability of submerged sandbar habitat in comparison to historic flow. Approximately 78% of open channel is available crane habitat (0-46.2 cm submergence class).
October	14.2	Same as end of September.
1-15 November	14.2	Same as October
16-30 November	2.8	River is essentially passive in terms of processes (vegetation encroachment) which control availability of crane habitat. Flow should be sufficient to maintain braided stream and aquatic habitat.
December	2.8	Same as November.

Channel Pattern Maintenance

Below areas where active channel degradation is occurring, successful maintenance of suitable whooping crane habitat depends on the ability of river flow to maintain the wide, braided channel and to maintain the process of thalweg formation and lateral migration. The shifting of the thalweg within the channel width will reduce vegetation encroachment from the banks. The braided channel will provide shallowly submerged sandbars for whooping crane roosting. Operation of the reservoir will interfere with the natural river regime; thus it is essential that certain hydrological processes, which maintain natural river patterns, be reproduced through future reservoir operation. It is a well-accepted concept that a river can maintain its pattern and cross section by a dominant discharge which occurs reasonably frequently. For the study reach of the Niobrara River, the formation and breakup of ice in the winter months were also found to be important processes in maintaining the wide, braided, and thalweg-shifting channel. The minimum flow requirements were therefore estimated based on the assumption that, below the degradation reach, the Niobrara River would maintain its current channel pattern provided the dominant discharge is achieved annually and the ice formation and breakup processes are preserved in the winter months from January to March. This goal may be achieved by the following 2 steps:

1. Provide adequate ice coverage over the entire channel width to reduce the vegetation growth within the channel and to increase the storage of water in the form of ice during January and February. This accumulated ice formation will provide ice jams during the March breakup. To ensure the success of this step, the river discharge in January and February should be maintained at 11.3 m^3/sec or more.

2. Release high flow in March to enhance the river scouring force during ice breakup. This step is to ensure that the young woody vegetation on the sandbars and bankline will be washed away and the thalweg will shift laterally within the channel. The river will undercut root systems of more mature woody plants where the thalweg scours against shorelines and islands. The river discharge for March is recommended to be 28 m^3/sec.

The Niobrara River frequently goes through several freeze-thaw cycles during winter. The minimum flow requirement for March should be considered as a flow regime that could be released whenever major ice breakup and high flow events occur. However, the total cumulative flow of 28.3 m^3/sec must be met for a period of 25 days. An operational restriction does not allow releases to exceed inflows; therefore, environmental release cycles will have to closely follow the natural cycles of high flows during the winter in order for the minimum environmental requirements to be met. This approach will require considerable flexibility in reservoir operational plans and consideration of short-term climatic cycles in planning environmental releases.

Woody Plant Establishment

Prevention of vegetational encroachment on the Niobrara depends on maintenance of channel scouring processes (described above) and on limiting the extent of woody plant establishment. The approach used for limiting woody species seedling establishment was to maintain flowing water over the majority of the channel area to ensure that most airborne willow and cottonwood seeds would land in water and be washed away. The life of these seeds is very short (5 days). As a consequence, water levels sufficient to cover most of the channel area would need to be maintained through the main seed-shed period (May through mid-June). Based on the aerial photography anaylses of water coverage at different river flow levels, a flow of 14.2 m^3/sec would cover most of the river channel with water, thus limiting potential seed germination sites. The area of river channel covered with water was estimated at 93% at 14.2 m^3/sec and 94% at high historic flows of 28.3 m^3/sec.

Water Depth Maintenance

Maintenance of suitable water depth at crane roosts was also recognized as a key factor for maintaining future habitat conditions. Literature review indicated that preferred depths at roosts are in the neighborhood of 2.5 to 20.3 cm (Frith 1976, Lewis 1976, Johnson and Temple 1980) but that whooping cranes may roost in water up to 46.2 cm deep (Johnson and Temple 1980). Aerial photography comparisons of the availability of sandbars within these submergence levels indicated a slight increase in available habitat as flow decreased from 28.3 to 13.2 m^3/sec. This was attributed to decreases in deepwater areas as the thalweg filled in and river flow spread over the river channel. Based on these results, a recommended flow level of 14.2 m^3/sec was chosen for crane use periods.

Potential crane use periods were selected as 28 March - 7 May and 12 September - 15 November based on all confirmed whooping crane sightings in Nebraska and South Dakota for the period 1949 to 1980 (data in Johnson and Temple 1980, Whooping Crane Recovery Team 1980, and unpubl. data provided by FWS).

Low Flow Periods

Finally, minimum flow conditions were prescribed for periods when the river is essentially passive in terms of the processes which maintain whooping crane roosting habitat. A recommendation of 2.8 m^3/sec was based on considerations that the flows should be sufficient for (1) the river to meander within the channel, and (2) maintenance of aquatic life. A theoretical analysis showed that the river channel can migrate laterally at flows to 2.8 m^3/sec. The recommendation meets the general criteria stated by Tennant (1976) for maintenance of aquatic life. It was recognized that Tennant's minimum criterion of 10% of mean annual flow is a general approximation and the flow recommendation was not based strictly on that criterion. Other considerations were as follows.

The importance of the Niobrara River to whooping cranes rests primarily on the quality of its roost sites because whoopers use a variety of wetland and upland habitats for feeding and will fly at least 1.6 and up to 24 km (Johnson and Temple 1980) from the roost to feed. Other potential feeding habitat occurs immediately adjacent to the Niobrara River and at greater distances. Because whooping cranes have been observed feeding in the river itself, it was assumed that a minimum flow condition should be established to maintain a potential food base. The exact food items taken by whooping cranes in the Niobrara River are unknown, but it was assumed that small minnows would be the most likely prey in shallow water near sandbars where the cranes would feed.

Prescription of minimum streamflow for the prey species was difficult because the behavior of the river at flow conditions lower than 11.3 m^3/sec could not be predicted with existing data. However, flowing water would be maintained at 2.8 m^3/sec and aquatic habitat would occur, although its extent would probably be reduced. The minnow species are adapted to shallow water conditions; consequently, it was assumed they would move into the habitat remaining during the periods of 2.8 m^3/sec flow.

Uncertainties were recognized in the base flow recommendation although previous recommendations were within that general magnitude. Negotiations during the EIS process resulted in a 2.8 cms minimum flow recommendation and the FWS recommended 5.6 m^3/sec in its biological opinion (Regan, D. M. 1979. Memorandum from Acting Regional Director, Region 6, U.S. Fish and Wildl. Serv. to Region. Dir., Lower Missouri Region, Bur. of Rec. regarding Section 7 consultation and biological opinion, O'Neill Irrigation Unit, Nebraska).

IMPACT ASSESSMENT

Assessments of future changes in whooping crane habitat were completed for "with dam" and "without dam" scenarios. For the "with dam" situation, impact assessment was based on future releases from Norden Dam predicted by a simulation model of reservoir operation, and on future changes in channel pattern predicted by the sediment transport model. Both models assumed 1928 to 1978 was representative of a typical 51-year cycle on the Niobrara. Thus the year 1928 was used as year 1 and year 52 in the 100-year modeling and predicted river flow was that which occurred in 1928, modified by projected upstream depletion and projected reservoir operation.

Projections of future conditions in the study area accounted for increased depletions in the system due to an increasing trend in water use in the drainage basin. WPRS estimated future upstream depletions in the system at year 2020 and this estimated demand was used as a constant throughout the simulation runs. Estimates were based on upstream irrigation developments which include the Mirage Flats Project, the Ainsworth Unit, and additional increases in groundwater-irrigated land. Projected reservoir operation was also based on irrigation demand associated with the O'Neill Unit and on WPRS design and operation criteria for the reservoir.

Analyses of the "without dam" situations were based on comparisons between predicted future flow conditions, historical conditions, and minimum streamflow recommendations developed in the study. Little quantification of expected changes was possible in contrast to the "with dam" situation, and impacts were expressed in terms of the relative risks associated with changes in river flow. For the long-term situation, future river flow was predicted over the 100-year period by substracting the estimated upstream depletions (discussed for the "with dam" situation), from the actual flow in each year of the 51-year historical record.

Effects of Norden Dam

In the "with dam" scenario, future hydrologic conditions in the study area would be affected primarily by the introduction of clearwater releases from the dam and by reductions in river flow associated with upstream depletions and the O'Neill Unit. Clearwater releases result in channel degradation. Flow depletions may negatively influence the processes which control vegetation encroachment in the river channel. Although flow depletions may also affect the river channel where degradation is actively occurring, the latter process is considered to be more important in terms of the potential severity of the impacts. Accordingly, the analysis separated the river into 2 reaches, 1 immediately below the dam in which degradation would actively occur and a 2nd reach downstream which would be unaffected by degradation.

After construction of a dam, sediment normally transported by river flow is deposited in the reservoir. The trapping of sediment in the reservoir is a function of reservoir size, reservoir shape, sediment characteristics, and reservoir operation. For Norden Dam, the trapping efficiency would be approximately 100%. Water in the reservoir would contain almost no sediment; therefore, when released it immediately begins to erode both the channel bed and banks. The channel bed would begin to degrade at a reach immediately downstream from the afterbay. As the water released from the dam moves downstream, it would gradually pick up sufficient sediment so that no further degradation occurred. However, with the passage of time, the slope in the degradation reach would decrease due to the greater erosion rate at its upstream end. With the decrease in slope and river velocity, less sediment would erode from the upstream reaches than during the initial stage and river flow would begin to erode sediment at locations progressively farther downstream.

Changes in the river in terms of bed degradation and channel width were predicted using the mathematical model over 100 years of reservoir operation. Summaries of the results of 10 and 100 years are included in Table 7. The maximum channel bed degradation after 100 years would be approximately 11.6 m just below the afterbay (about 1.6 km below Norden Dam site). The degradation process would extend approximately 21 km from the Norden Dam site after 100 years.

The direct effects of the clearwater releases from the dam would indirectly affect whooping crane habitat through loss of wetland feeding habitat and decreases in roost habitat quality. Wetland habitats adjacent to the river are directly tied to the groundwater system as it flows into the Niobrara river channel. Lowering of the bed elevation in the river would lower the groundwater table and adjacent wetland areas could be dried. A drop in channel elevation of 0.3 m would very likely change sedge and spikerush meadows to a Kentucky bluegrass-dominated meadow containing scattered shrubs; a drop in channel elevation of more than 0.3 m would most likely result in the invasion of indigo bush, sandbar willow, and peachleaf willow into meadow areas. Within the study area, meadow wetland areas are most abundant in the easternmost reaches. The 0.3-m degradation level would occur about 21 km below Norden Dam site after 100 years; thus most meadow areas would be unaffected by the degradation process. However, within the degradation reach, approximately 44 ha of wetlands would very likely be dried up when the groundwater table was lowered. About 37 ha of this wetland is considered potential whooping crane feeding habitat.

Table 7. Predicted changes in Niobrara River channel bed elevation and channel width resulting from the simulated operation of Norden Dam.

Location (in km from Norden Dam)	Channel bed degradation (m) 10-year	Channel bed degradation (m) 100-year	Total channel width (m) Original	Total channel width (m) 10-year	Total channel width (m) 100-year
2.97	-2.76	11.68	358.3	182.1	95.8
4.67	-0.33	9.53	295.2	269.6	102.5
6.94	-0.23	7.17	289.7	272.1	115.3
8.71	-0.16	5.64	160.1	157.4	105.8
11.45	-0.08	3.79	269.3	264.4	146.4
13.71	-0.01	2.62	221.1	220.5	151.6
21.77	-0.00	0.08	268.4	268.4	264.1

Lowering of the riverbed elevation by channel degradation would also influence crane habitat by decreasing the quality of roost habitat, specifically by creating high banks and encouraging vegetation encroachment. Increases in depth of about 0.6-0.9 m over only a portion of the entire river channel leaves higher elevation areas on the channel edge which are not subject to high flows and ice scouring. These factors in combination are the major source of instability in the river system and the loss, or reduction, of their effect means that sediment would cease to be shifted in the channel margins, vegetational invasion would be unchecked by scouring, and outlying areas would rapidly become stabilized with vegetation. Thus, the degradation process would be expected to result in a progressive reduction in the width of the river channel and a change from a wide, braided channel pattern to a more narrow, meandering pattern.

River widths in Table 7 are the most accurate predictions of future change, because these river cross sections were modelled. Between the individual cross sections, predictions of future change became less accurate because the channel characteristics at a given point may vary,considerably from those at the measured river range. With this limitation in mind, estimates of future unobstructed channel widths were made for crane roost quality reaches affected by degradation. Estimates were made using the degradation-channel width relationship developed for the model, by interpolating between modelled results for specific river ranges. Based strictly on projections of unobstructed channel widths, the degradation process would be expected to change 13.2 km of habitat from preferred to low-quality or unacceptable within 100 years. Beyond the degradation reach, whooping crane habitat could potentially be affected by changes in instream-flow regimes, if these changes were sufficient to adversely affect the availability of crane habitat, either directly or through encroachment by vegetation.

Recommended minimum flows were intended as threshold levels for negative impact and as such were a useful base for comparison of future flow conditions. Projected flows were examined in terms of the relative risks of adverse change although it was not possible to state quantitatively the effects of future flow conditions. Future monthly flow conditions were projected for each year in the 51-year cycle (Table 8). Projected future conditions would meet or exceed the minimum flow recommendations for all months except March. This indicates that criteria should be met related to sandbar availability during crane use periods, maintenance of aquatic environments, prevention of seedling establishment, and ice formation. Lower than recommended flows in March, combined with a reduction of the dominant discharge from about 28.3 m^3/sec to about 22.7 m^3/sec, raised questions regarding the future ability of the river to (1) maintain its current channel width, and (2) mechanically damage invading vegetation through the combined effects of ice and high flow. Further analysis of projected March flows indicated that there would probably be flow shortages (on the average) in 31 of 51 years. The severity of impact of these flow reductions was not quantifiable because higher than recommended flows of shorter duration could maintain the channel as effectively as the longer duration flow of 28.3 m^3/sec--assuming favorable climatic conditions caused ice breakup to coincide with high flows. However, projected March shortages are considered to represent a risk that river scouring processes may be insufficient to retard vegetation encroachment into the channel. If the operational plan is provided with considerable flexibility to release high flow (28.3 m^3/sec) whenever the climatic conditions are favorable for ice breakup, and upstream inflow is larger than 38.2 m^3/sec in the winter months, the risk of failing to maintain the channel pattern would be reduced.

Future Effects Without Dam

Under the "without dam" situation, future changes of the Niobrara River in the study reach will be caused mainly by the natural fluctuation of the river system and upstream flow depletions. Analysis of the "without dam" situation was limited because the factors controlling channel width fluctuation (other than degradation) are still poorly understood, and the interaction between surface flows and ice is a highly variable phenomenon. In the short-term, channel width shrinkage may continue in the Norden-Meadville reach where bed degradation is known to have occurred; it is expected that reaches 32-40 km downstream from the proposed dam will most likely remain stable as they have over the period of record (1938-1980). In the long-term, there will be reductions in flow due to increased upstream water use (Table 8). As a consequence of these flow reductions, there is a risk that whooping crane roosting habitat areas will be reduced. The major differences between the "with dam" and "without dam" situations, under depleted flows, are (1) the relative magnitude of the risks involved, and (2) the fact that river flow would not be regulated in the "without dam" situation. The "without dam" situation for March would be closer to historical conditions and was therefore considered to present lower risk potential. Unregulated river flow in the "without dam" situation also offers greater natural flexibility and increased likelihood that higher than recommended river flows will occur on a daily basis with sufficient frequency to maintain the wide, unvegetated river channel. In summary, it is believed that though there is some quantifiable risk that the channel

Table 8. Summary of historical and projected inflows and recommended and projected releases (m^3/sec).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Historical inflow	25.7	26.2	32.2	28.8	28.5	25.9	21.5	20.3	20.9	23.3	24.4	25.8	25.3
Projected future inflow[a]	22.3	23.7	24.3	25.9	23.3	18.0	14.7	13.8	13.7	15.8	17.6	20.8	19.5
Recommended environmental release	11.3	11.3	25.9	14.2	14.2	8.5	2.8	2.8	8.5	14.2	8.5	2.8	10.4
Projected release	15.2	18.4	23.9	22.1	20.1	12.4	3.5	2.9	8.8	14.2	8.9	5.5	13.0

[a] Based on historic flow records less projected upstream depletions. Predictions of future depletions were provided by WPRS.

pattern will change, channel maintenance factors will continue to operate in the system. It was not expected that the future situation without the dam will have an important effect on downstream wetland complexes, because water surface elevations will change very little as compared to the present.

CONCLUSIONS

The Niobrara River Whooping Crane Habitat Study provided information for use in future consultation between WPRS and the FWS. Consultation was still occurring in July 1981. The study predicted that whooping crane habitat on the Niobrara River would be reduced as a consequence of clearwater releases from Norden Dam. Such reduction would result from channel degradation that would be expected to extend approximately 21 km from the dam in 100 years. Minimum flow recommendations were developed to ensure maintenance of habitat conditions beyond the degradation reach. Based on current knowledge, recommended flows should be sufficient to maintain desirable crane habitat characteristics. Uncertainties and risks are recognized and a long-term monitoring and mitigation plan should be implemented if the dam is constructed. Implementation of the minimum flow recommendations remains somewhat problematical because future upstream water uses may reduce flow in the river below the specified minimum. Thus, flexibility will have to be developed in the dam regulation plan to meet the minimum flow regime recommended in the study. It is recommended that this flexibility be gained through a 3-year monitoring study of ice-high flow interactions and the effectiveness of various flow magnitudes and durations in maintaining channel pattern.

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WHOOPING CRANE MORTALITY AT THE PATUXENT WILDLIFE RESEARCH CENTER, 1966-1981

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Abstract: Causes of whooping crane (*Grus americana*) mortality from 1966-81 at the Patuxent Wildlife Research Center included: infectious diseases (31.7%), parasitic diseases [primarily disseminated visceral coccidiosis](19.5%), anatomical abnormalities [primarily leg rotation] (19.5%), intraspecific aggression (7.3%), and miscellaneous conditions (22.0%). The 41 deaths included 28 (68.3%) downy young, 3 immatures (7.3%), and 10 (24.4%) adults. Downy young were more susceptible to various mortality factors because of low resistance and high susceptibility to the stresses of captivity. Mortality was seasonal with 36 deaths (87.8%, May-August) being associated with the period of egg production and rearing of young. Much of the mortality occurred before current management techniques and rearing methods were developed. Husbandry, disease control, and crane rearing procedures now being used should enhance the survival of captive whooping cranes and their offspring.

The Endangered Wildlife Research Program was established in 1966 at the Patuxent Wildlife Research Center (Laurel, Maryland) for the scientific study of native endangered species (Erickson 1968). The objectives of the program, to assemble captive breeding stock and to develop effective methods of propagating stock for restoring wild populations, were directed primarily at species such as the whooping crane which had not responded adequately to conventional measures taken to assure their survival. Five years of preliminary research with the sandhill crane (*G. canadensis*) had been completed at Monte Vista National Wildlife Refuge, Colorado, before the site at the Patuxent Center was selected (Erickson 1975).

Sufficient research had been completed by 1966, at the Colorado field station, to permit undertaking a major effort to propagate whooping cranes. One whooping crane was transferred from Colorado to Patuxent in 1966 and 1 egg was taken from each of six 2-egg clutches in Wood Buffalo National Park, Canada, and translocated to the Patuxent Center in 1967. From 1968-74, 44 additional eggs were taken from the wild, and the chicks hatched and raised from them formed the nucleus of the Patuxent flock (Kepler 1978). The main goals of the effort were (1) to maintain birds in captivity in the event of a catastrophic loss of the wild flock, (2) to produce offspring for release to the wild, (3) to enable research on captive cranes, and (4) to provide mates for unpaired whooping cranes at other institutions (Kepler 1978).

The 1st breeding of whooping cranes at Patuxent occurred in 1975 when 1 female laid 3 eggs. Since then, several additional females have become productive. Many techniques that were developed with sandhill cranes have been applied to the breeding and rearing of whooping cranes. However, because whooping cranes are behaviorally somewhat different from sandhill cranes, modifications in propagation techniques have been required and propagation research continues in an effort to improve conditions for captive pairs and their young (Erickson and Derrickson 1981).

There is little published about captive whooping crane mortality. Therefore, this review was made of mortality at the Patuxent Center from 1966 to 1 July 1981. Some of the mortality factors that have been identified are controllable; thus, this review is a useful reference for others who have or contemplate captive rearing of whoopers or other species of cranes.

METHODS

Most of the whooping crane eggs hatched at Patuxent through 1977 were artificially incubated. Each egg was checked twice daily and transferred to a hatcher after 28 days of incubation. Within 24 hours after hatching, the chick was placed on a crushed sugar-cane substrate or on indoor-outdoor carpeting, and maintained indoors under heat lamps. Water was available in gallon-sized (3.8 l) poultry founts, and feed was initially placed in shallow dishes or in small gravity-flow poultry feeders. Since 1978, most whooping crane eggs have been incubated and hatched, and the young subsequently reared by foster-parent pairs of sandhill cranes in outdoor pens.

After the period of most rapid growth and development, the hand-raised chicks were moved outdoors to the juvenile quarters. These pens are managed on a 3-year rotation system in order to reduce the buildup of parasites and bacteria in the soil. Cranes are housed in this area for about 3 months and then moved to subadult enclosures (Erickson 1975).

Both subadult and community enclosures were spacious, each with shade shelters and several open-fronted shelters which housed 2 hanging-type, gravity-flow poultry feeders (Erickson 1975). Fresh water was provided by constantly flowing, elevated drinking cups. Cranes generally remained in the community pens until each selected a mate or was force-paired. Then they were moved into breeding enclosures (Kepler 1978) which were visually isolated from adjacent pens. Special feeding and sanitation procedures, quarantine policies, predator and rodent control, pen rotation, removal of foreign material from pens, and animal examinations have been important aspects of husbandry and disease control at the Patuxent Center (Carpenter 1977).

For the purposes of this report, cranes were assigned to 1 of 3 age groups based on their plumage: downy young (<2 months of age); immatures (2 to 12 months); or adults (>12 months of age). Diagnoses were based on a combination of clinical signs, necropsy results, and microbiologic, parasitologic, and histopathologic findings. Postmortem examinations were routinely performed on all dead birds and essential tissues were preserved for study. Details of the diagnostic procedures and methods have been reported previously (Carpenter et al. 1976).

RESULTS

Between 1966 and 1 July 1981, 41 whooping cranes (28 downy young, 3 immatures, and 10 adults) died at the Patuxent Center (Table 1). Infectious diseases, parasitic diseases, anatomical abnormalities, and intraspecific aggression resulted in 32 (78.0%) of the deaths. Other causes were responsible for 9 (22.0%) of the losses. Twenty-seven (65.9%) of the birds died in May-June, 9 (22.0%) in July-August, 2 (4.9%) in January, and 1 (2.4%) each in February, April, and November (Fig. 1). Sixteen (39.0%) were males, 17 (41.5%) females, and the sex of 8 (19.5%) was undetermined.

Table 1. Mortality in whooping cranes at the Patuxent Wildlife Research Center, 1966-July 1981.

	Number of individuals			Total	
Cause of death	Downy young	Immature	Adult	Number	%
Infectious disease	12	0	1	13	31.7
Parasitic disease	7	0	1	8	19.5
Anatomical abnormality	5	2	1	8	19.5
Intraspecific aggression	1	0	2	3	7.3
Other	3	1	5	9	22.0
Totals	28 (68.3%)	3 (7.3%)	10 (24.4%)	41	100.0

Infectious Diseases

Infectious agents, particularly bacteria, were the primary cause of the death of 13 (31.7%) captive whooping cranes, and some bacteria, including *E. coli*, *Pseudomonas* sp., *Proteus* sp., *Klebsiella* sp., *Bacillus* sp., *Staphylococcus* sp., *Micrococcus* sp., *Streptococcus* sp., and *Salmonella* type B, contributed to the deaths of others. *Pseudomonas* sp., *Streptococcus* sp., and B hemolytic *E. coli* were among bacteria cultured from the lungs, air sacs, alimentary tract, and peritoneal cavity of the 13 cranes. *Proteus* sp. and *Bacillus* sp. were contributing factors or secondary invaders in some of these cases. Except for one 6-year-old adult, these cranes were an average of 8.5 days of age at the time of death.

Pneumonia (characterized by consolidation of lung tissue, vascular congestion, and frothy airways) and airsacculitis were the primary factors in the deaths of 6 (14.6%) downy young cranes. Other primary causes of death associated with infectious agents included pneumonia (1 bird, 2.4%), airsacculitis (1 bird), enteritis (3 birds, 7.3%), omphalitis (1 bird), and peritonitis (1 bird). It appears, therefore, that young birds are especially predisposed to infection during hatching or other environmental stresses.

Parasitic Diseases

Based on clinical, histopathologic, and electron microscopic findings, the deaths of 5 whooping crane chicks and a 9-year-old female, all reared in outdoor pens, were attributed to an overwhelming systemic infection with an intracellular protozoan parasite (*Eimeria* sp.). In most of these chicks the coccidia caused granulomatous bronchopneumonia, hepatitis, myocarditis, necrotizing splenitis, and moderate-to-severe enteritis. In 3 birds the enteritis was also associated with the presence of several nematodes or acanthocephalans, or both.

Death of the adult crane was associated with a granulomatous enteritis caused by coccidia in the lamina propria, which resulted in dehydration, renal impairment, and visceral gout (Carpenter et al. 1980). Concomitant granulomatous hepatitis associated with the intracellular protozoan was a factor contributing to death.

Acanthocephalans appeared to be responsible for the deaths of two 18- to 20-day-old cranes. Both birds died with peritonitis and ascites, with a concurrent pneumonia in 1 bird, resulting from intestinal perforation associated with acanthocephalan activities. Secondary coccidiosis was a contributing factor in 1 chick.

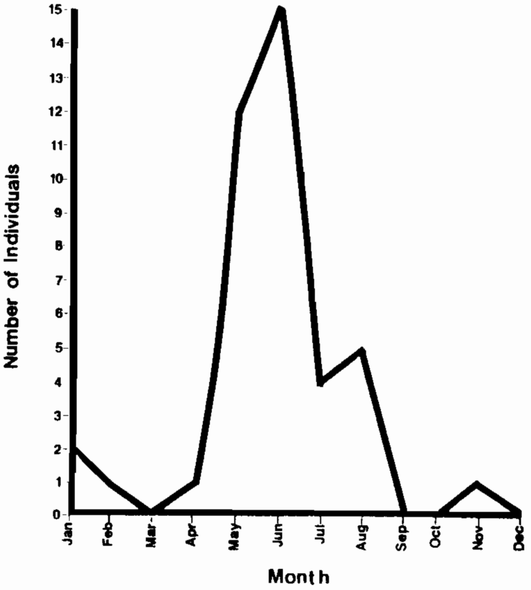

Fig. 1. Monthly incidence of mortality of 41 whooping cranes at the Patuxent Wildlife Research Center, 1966 - July 1981.

A low incidence of gapeworm (presumably *Cyathostoma coscorobae*), roundworm, acantocephalan, and coccidial infections was observed in several other whooping cranes. Although these parasites may have been a contributing factor in a few instances, they were generally considered incidental.

Anatomical Abnormalities

Anatomical problems were considered the underlying cause in the deaths of 8 (19.5%) cranes; except for 1 adult, all were between 4 and 67 days of age (4 chicks developed leg and toe problems within 2 days posthatching). These conditions included perosis, crooked and curled toes, lateral rotation of the tibiotarsus, spraddle legs, and bilateral tibial subluxation.

In 1967, a calcium-phosphorous imbalance appeared to predispose 1 chick to rotation of the tibial-femoral joint and a 2nd chick to perosis. Another chick, malpositioned in the egg, hatched with a twisted neck and displayed central nervous system signs (rolling to the left, staggering, and head pressing), presumably associated with cerebral edema. The latter bird eventually died due to dehydration, inability to ingest food, and stress. Most of the 8 cranes died as a result of stress, chronic debility, concurrent anorexia, and secondary bacterial infections (panopthalmitis, air sacculitis, septicemia, and toxemia) resulting from impaired ambulation.

Intraspecific Aggression

Intraspecific aggression is a characteristic of most species of animals and generally occurs during the formation and maintenance of dominance hierarchies, selection of mates, and in acquiring or defending territory, food, or water (Carpenter et al. 1976). Intraspecific aggression frequently manifests itself when birds are moved into a new pen or, more typically, when an individual accidently enters the pen where a territory has already been established. At the Patuxent Center, the death of 3 (7.3%) whooping cranes was attributed to wounds inflicted by conspecifics.

One whooping crane chick hatched by sandhill crane foster-parents was apparently killed by the adult male within 1 day after hatching. This aberrant behavior reflects either the lack of experience of this male in raising chicks or his extreme aggressiveness.

An adult female was killed by her mate after 7 years of coinhabiting the same pen and after 5 years of egg production. Penetrating wounds pierced her brain, eyes, neck, and mandible. Because of their history of compatibility, it was surmised that an underlying factor such as a disturbance-induced accident had impaired the female and resulted in the male attacking her. Four months later, a 3-year-old female was placed in an adjacent pen and the birds were frequently observed. After months of unison calling and apparent compatibility, the male was placed in the female's pen. Observations indicated that the birds were compatible, frequently unison called, mutually preened, and eventually displayed courtship and precopulatory behavior during the next 4 months. Then, without any apparent reason, the male killed this 2nd female.

Other Causes of Mortality

Nine (22.0%) whooping cranes died from causes other than bacterial infections, parasites, structural abnormalities, or aggression. One bird died from necrosis of the liver and of the lymphoid elements of the intestine; etiology of these lesions was not determined. An immature crane, debilitated by a foreign body penetrating the gizzard, died from anorexia, visceral gout, and secondary aggression by pen mates.

A chick that apparently hatched in a weakened condition died from secondary trauma from foster-parents attempting to stimulate it posthatching. Maggot infestation and mild pulmonary congestion contributed to the bird's death. A 7-year-old female died from shock, cloacitis, salphingitis, and a maggot infestation of the perineal region because a crushed egg obstructed the oviduct and cloaca.

Other mortality factors included: (1) dehydration, starvation, and stress, with secondary bacterial infection; (2) shock due to hemorrhage from a damaged blood quill; (3) predation, presumably due to a fox; (4) rupture of a major mesenteric vessel; and (5) stress and postsurgical shock following repair of bilaterial tibial fractures.

DISCUSSION AND CONCLUSIONS

Causes of mortality were determined for 41 whooping cranes that died from 1966 to 1 July 1981 at the Patuxent Wildlife Research Center, and included: infectious diseases (31.7%), parasitic diseases (19.5%), anatomical abnormalities (19.5%), intraspecific aggression (7.3%), and miscellaneous causes (22.0%). Age incidence of mortality consisted of 28 (68.3%) downy young, 3 (7.3%) immatures, and 10 (24.4%) adults. Downy young were more susceptible to various mortality factors because of low resistance and high susceptibility to the stresses of captivity (Carpenter et al. 1976). Most of the deaths, therefore, occurred in May and June corresponding with the period of breeding and hatching.

The clinical, histopathologic, and electron-microscopic findings in whooping cranes infected with disseminated visceral coccidiosis were similar to those in sandhill cranes at the Patuxent Center found to be infected with *E. reichenowi* and *E. gruis* (Carpenter et al. 1979, Carpenter et al. 1980). Disseminated visceral coccidiosis only resulted in the death of a few sandhill and whooping cranes between 1966 and 1975 (Carpenter et al. 1976), but has been a more important cause of death in both species in recent years. These protozoa also have been reported in free-ranging whooping cranes (Forrester et al. 1978); however, the eimerians represent a special problem for crane chicks (which are more susceptible to parasites and diseases than older birds) raised in captivity. Because of the opportunity for a buildup of these parasites in the soil in captivity, parasitism resulting in extraintestinal movements of these organisms remains a potential health problem for whooping cranes and sandhill cranes in confinement.

As with other rapidly growing, long-limbed birds, hand-reared whooping cranes appear to be predisposed to leg injuries and abnormalities. Management factors that may contribute to development of leg problems include incubation temperatures, hatching and rearing substrates, nutrition, ambient temperature, illumination, external stimuli, and exercise level (Carpenter et al. 1976). Improvements in hatching, rearing, and feeding programs, however, have greatly reduced the incidence of leg problems in cranes at the Patuxent Center. In some situations, daily food or energy intake of cranes has been limited to an amount that will avoid excessive weight gains; in other instances, a chick's activity level has been increased so that excess energy is expended in exercise. Foster incubation, hatching, and rearing of whooping crane chicks by sandhill cranes since 1978 also has provided a useful means of meeting exercise requirements, because chicks follow their parents through the tall grass in the enclosures in search of insects and other supplementary food items. None of the foster-parent-reared whooping cranes has developed leg or toe problems. A diet also has been developed at Patuxent to promote slower growth in sandhill cranes. This diet, formulated to contain a low sulfur amino acid level, appears to be suitable for slowing the growth rate of hand-raised whooping cranes, thereby reducing the risk of abnormal leg development.

Trauma, consisting of intraspecific aggression, injuries, and accidents, was the most important cause of death of sandhill cranes at the Patuxent Center. Aggression was a particular problem with birds raised in community pens; 18% of the sandhill crane deaths resulted from intraspecific aggression (Carpenter et al. 1976). However, only 7.3% of whooping crane deaths could be attributed to intraspecific aggression because whooping cranes are usually raised under more isolated and carefully managed conditions.

Husbandry and management practices at the Patuxent Center are continually being evaluated and improved in response to mortality and morbidity factors in order to maximize productivity and minimize losses. For example, leg problems have been basically eliminated through foster-parent-rearing of young, or by exercise and dietary restrictions, and losses to extraintestinal coccidia have been greatly reduced through intensified husbandry and the use of coccidiostats in the feed and water (Carpenter 1978). During the past 15 years, we have learned a great deal about maintaining and breeding whooping cranes in captivity. Improved success in breeding and maintaining this species in captivity seems assured because many crane deaths at Patuxent occurred before current management and rearing methods were adopted.

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DYNAMICS OF SUBADULT FLOCKS OF WHOOPING CRANES AT ARANSAS NATIONAL WILDLIFE REFUGE, TEXAS, 1978-1981

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Abstract: Subadult flocks of color-banded whooping cranes (*Grus americana*) were studied on the wintering grounds at Aransas National Wildlife Refuge, Texas, from 1978-79 through the 1980-81 season. Subadult flock composition, habitat selection, movements, and intraflock relationships were examined. In early fall, large aggregations of subadults and unpaired adult cranes often exploited unusual food concentrations on the refuge burns and in the salt marsh. These aggregations were temporary and dispersal occurred when the food resource became depleted. Dunham Bay was a traditional use area for subadult flocks from 1976-77 on. During the 1980-81 winter, flocks were also found in Sundown and St. Charles Bays. Flock composition was not stable and fluctuated during each season. Color-banded 3- and 2-year-olds have been observed pairing with unbanded birds.

The subadult stage in the life cycle of a whooping crane begins at about 10 months of age when the young crane is driven off by its parents. From that time until the crane becomes sexually mature it is considered a subadult. During this subadult stage a whooping crane tends to associate in small flocks with other subadults and nonbreeding adults. Until recently there were few studies of the behavior of the subadult whooping cranes in the Wood Buffalo-Aransas population (Kuyt 1979, Blankinship and Kuyt in this proceedings) because of difficulties in identifying and following individual cranes over a period of years. Flocks of apparently nonterritorial whooping cranes have been observed on the wintering grounds for several years and it has been assumed that these were birds which had not yet attained sexual maturity (Blankinship 1976).

Since the summer of 1977, prefledged whooping cranes have been individually marked using colored leg bands on their breeding grounds in Wood Buffalo National Park (WBNP), Canada (Kuyt 1978). During the 1980-81 winter there were 21 color-banded whooping cranes in the Wood Buffalo-Aransas population including 7 from 1977, 5 from 1978, 5 from 1979, and 4 from 1980. Such a sizable group of individually identifiable whooping cranes has afforded a unique opportunity to follow in detail the life cycle of this rare bird.

The National Aubudon Society has since 1970 studied the behavior and habitat use of whooping cranes wintering on the Texas coast. As a part of this ongoing research, our study has the following objectives: (1) evaluate subadult flock composition, (2) examine subadult intraflock and interflock relationships, (3) investigate pair formation within flocks, and (4) monitor habitat selection and local movements of subadult flocks of whooping cranes. We expect to continue this subadult flock study through the 1981-82 winter. This preliminary report will focus on flocking behavior and other social interactions during the 1980-81 winter at Aransas National Wildlife Refuge (ANWR), Texas.

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STUDY SITE

Aransas National Wildlife Refuge, located on Blackjack Peninsula 60 km northeast of Corpus Christi, Texas, consists of approximately 21,862 ha of bay shorelines, salt marsh and flats, grasslands, and live oak (*Quercus virginiana*) and redbay (*Persea borbonia*) thickets. Approximately

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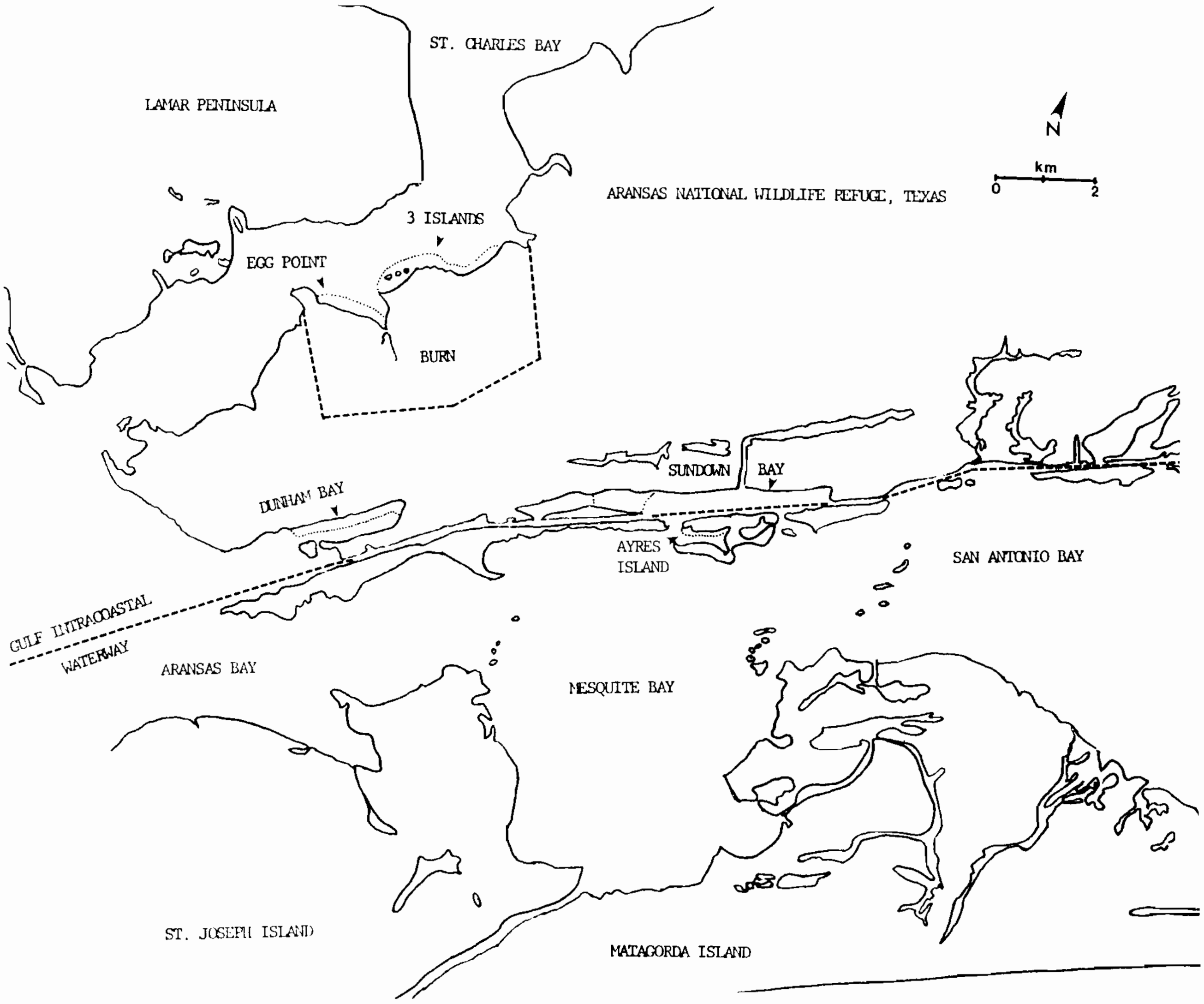

Fig. 1. Locations of [illegible] flock use areas at Aransas National Wildlife Refuge, Texas, in 1980-81. Locations of burn and specific use sites outlined with dashed lines.

7,692 ha of nearby Matagorda Island are presently administered as part of ANWR. Most of the field work was concentrated in 4 areas (Fig. 1): western shore of Dunham Bay; middle and southern Sundown Bay: eastern shore of Ayres Island; and eastern shore of St. Charles Bay from Egg Point to Little Devil Bayou. These shorelines are accessible via a small boat and allow unobstructed, close-up observation of the cranes.

All of the study areas except St. Charles Bay border the Gulf Intracoastal Waterway (GIW). The whooping cranes are exposed throughout the winter to barges, tugs, oilfield crew and service boats, commercial fishing boats, and recreational craft. Dunham and Sundown Bays are both shallow (0.15-0.6 m) thus effectively preventing most larger boats from entering these bays. Sports fishermen regularly enter the bays in the fall but are rarely seen during winter. The western shore of Ayres Island borders the GIW. The southern ends of adjoining Ayres and Roddy Islands border Wynne's Cut, a narrow channel used by crew boats and recreational craft for access to Mesquite Bay. St. Charles Bay is deeper than the other 3 sites (0.3-1.5 m) and is a popular fishing and hunting area. Seasonal waterfowl hunting is allowed along the nonrefuge portion of the western shore of St. Charles Bay. Sports and commercial fishermen operated crabtraps and trotlines along the eastern shore throughout the season.

Salt marshes associated with each study area are dominated by: *Spartina alterniflora*, *Salicornia* spp., *Borrichia frutescens*, *Monanthochloe littoralis*, *Distichlis spicata*, *Batis maritima*, and *Lycium carolinanum*. In the bays, the stout razor clam (*Tagelus plebeius*) is the most common bivalve (Harper 1973, this study) and is a primary food item of the cranes while at ANWR. Blue crabs (*Callinectes sapidus*) are also available and an important crane food item. Other invertebrates consumed by whooping cranes in the marsh include fiddler crabs (*Uca* spp.) and the pulmonate snail (*Melampus bidentatus*)(Allen 1952, this study).

Since 1973-74 ANWR personnel have practiced prescribed burning of upland habitat as a means of reducing heavy grass cover, controlling shrubby vegetation, and stimulating the new growth of grasses and forbs. Burned areas on Blackjack Peninsula have been attractive to whooping cranes as feeding sites. Cranes have been observed feeding on burned acorns and on snails in small ponds on the burns (this study). Cranes may feed on insects, other invertebrates, and snakes on the burns (Labuda and Butts 1979).

In late October and early November 1980, approximately 976 ha were burned near St. Charles Bay (Fig. 1). This was the 1st time that this site had been burned in 2 years. Shortly thereafter, large numbers of sandhill (*Grus canadensis*) and whooping cranes were observed feeding on the burns during aerial censuses (ANWR files). Observations of cranes on the burns were limited due to the extreme wariness of the birds in this environment.

METHODS

Behavioral observations of color-marked subadults during the 1978-79 and 1979-80 winters were made from boats operating in the GIW and in various bays at ANWR. Marked birds were observed 1 to 3 times weekly from a boat or fixed-wing aircraft. Flock composition and movements were determined from these observations. Daily behavioral observations began the 1st week of November 1980 and, except for 19-31 December or severe weather conditions, continued through April 1981.

Most observations were made from a chair placed in the water behind a 4.12-m outboard boat. GIW platform markers were used as elevated observation posts to locate birds in the marsh. Observations were made using a 15-60X zoom telescope and 7 x 35 binoculars.

As previously noted, study birds had been color-banded as prefledged chicks in WBNP by the Canadian Wildlife Service (Kuyt 1978). Combinations of distinctive color bands allowed ready identification of individuals and age classes. Two subadult birds, 1 from 1977 and 1 from 1979 were not banded as chicks and are therefore unidentifiable.

A subadult flock was defined as a group of 2 or more birds, at least 1 of which was banded, in close proximity to each other and interacting. The method used in observation was focal-animal sampling. This method records spontaneous and intensive social interactions within a group as well as flock members' nonsocial behaviors. A record was made of the length of each sample period and, for each focal individual, the amount of time during the sample that the individual was actually in view (Altmann 1974, Lehner 1979).

Descriptions of behavioral units were adapted from the ethogram for the red-crowned crane (*Grus japonensis*) devised by Masatomi and Kitagawa (1975), from whooping crane postures described by Kepler and Archibald (unpubl. manuscript), and from ethological descriptions of sandhill cranes by Nesbitt and Archibald (1981) and Voss (1976). Each behavior was coded to a combination of letters and numbers and recorded on a data sheet.

Average flock size and age-class composition were calculated using the high bird count for all 1st 0.5-hour behavioral sampling periods, and all incidental sightings. All adult-plumaged, unbanded birds were defined as over 4 years old. Therefore, the 2 birds not color-banded, 1 in 1977 and 1 in 1979, if present, would have been categorized as over 4 years old.

RESULTS AND DISCUSSION

1976-77 Through 1979-80 Winter Seasons

Aggregations of 5-10 whooping cranes frequented the western shore of Dunham Bay during 1976-77 and 1977-78 winters from late November until the birds' spring departure the 1st week of April. As many as 17 birds were observed using a burn in the Point Pasture area (southwest corner of Blackjack Peninsula) in fall of 1976, but flocks were not seen at nearby Egg Point or Three Islands (Fig. 1).

In early November 1978 a loose aggregation of birds formed in the marsh and sloughs northeast of Dunham Bay. By 7 December the birds moved to the western shore of Dunham Bay. A group of 6-13 (usually 9-10) birds used the area until late March.

During the 1979-80 winter a flock congregated in a pond on Bludworth Island which contained a concentration of blue crabs. This activity was 1st noted on 10 November 1979 and peaked around 18 November when 19 birds were observed there including at least 7 of the 13 existing marked birds. This concentration of whooping cranes slowly began to disperse and by 1 December there was increased use of sloughs and marshes west of Sundown Bay. Dunham Bay had not consistently attracted flocks during this early season. By mid December, however, 3 birds began using the western shore of Dunham Bay. Numbers increased to 6-7 birds in early February and remained at that level until the end of March.

1980-81 Winter Season

Ten whooping cranes, including 2 with colored bands, were counted on the refuge 14 October during the weekly aerial census. By the end of October 45 whoopers were present (ANWR files).

Dunham Bay.--Throughout November, field observations were concentrated in Dunham Bay (Fig. 1) because it had been a traditional location for subadult flocks. Most of the time, however, only unbanded pairs were observed on Grass Island (entrance of Dunham Bay), and along the eastern and western shore of the bay.

During the 1st half of the month small groups of 3, 4, and 5 cranes were observed once each during 3 days of observations. Only one 2-year-old and two 3-year-olds were positively identified during this time. A territorial pair was observed chasing the group of 4 at the southern end of the bay.

During the 2nd half of November, flocks of 3 and 6 were observed only once each during 6 field days. The flock of 3 included two 1-year-olds and an unbanded bird. These birds were seen here again in January and stayed in the bay the rest of the season.

Egg Point - Bill Mott Bayou.--Weekly aerial surveys during November located 10-26 whooping cranes on the newly burned plots near St. Charles Bay. On 30 November a large flock of 12-14 whooping cranes, including 7 subadults, was located in the St. Charles Bay area known as Egg Point-Bill Mott Bayou (BMB)(Fig. 1).

Over the following 2 weeks, flocks ranging in size from 3-25 were observed along this shoreline (Fig. 2). Feeding was the primary activity of the flocks, requiring about 66% of their time. Small and large groups moved up and down the shoreline, sometimes feeding in water thigh deep. A territorial male and his mate chased groups back toward BMB when these groups ventured too close to Egg Point.

The flocks at Egg Point-BMB varied in their age-class composition (Table 1). Typically more than 50% of the birds were unmarked, indicating that they were at least 4 years old. Only a few of these unbanded birds appeared to be paired. Among 17 banded subadults in the Wood Buffalo-Aransas population, all but 3 were observed in these Egg Point flocks during December. The 3-, 2-, and 1-year-olds were approximately equally represented throughout the flocks. Certain banded subadults consistently associated with each other: arriving, feeding, resting, and departing together. Later on these cranes were located on other sites as separate flocks.

An unbanded chick and its parents joined the Egg Point-BMB flock on 4 days. This family tolerated the nearby presence of another unbanded bird. The bird arrived with the family and

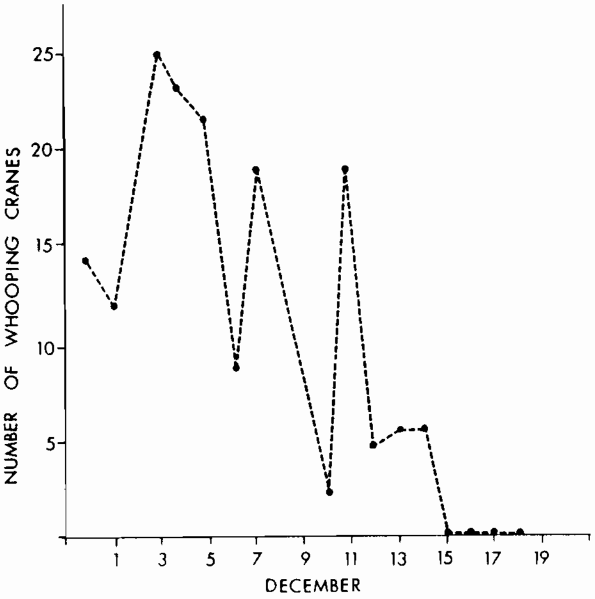

Fig. 2. Peak flock size per day at Egg Point-Bill Mott Bayou, St. Charles Bay: 30 November-18 December 1980.

Table 1. Average monthly flock size and percentage age-class composition by location at ANWR from November 1980 - April 1981.

	Flock size		Percentage age class				
Location	N	$\bar{X}$	≥4	3	2	1	<1
Durham Bay							
November	5	4.6	42	25	13	21	0
December	No observations		-	--	--	--	--
January	13	5.7	51	8	15	23	3
February	3	3.7	53	0	0	47	0
March	11	3.2	33	0	0	67	0
April	10	3.1	33	0	0	67	0
Egg Point							
November	1	12.0	42	17	25	17	0
December	11	9.2	51	17	14	16	2
January	2	3.0	50	50	0	0	0
February	2	4.0	37	10	27	27	0
March	No flocks		--	--	-	--	--
Three Islands							
November	No observations		--	--	--	--	--
December	13	5.2	51	31	15	3	0
January	11	4.5	55	45	0	0	0
February	2	4.0	37	20	27	17	0
March	No flocks		--	--	--	--	--
Sundown Bay							
November	1	4.0	50	0	25	25	0
December	No observations		--	--	--	--	--
January	15	7.8	44	8	29	20	0
February	6	9.2	34	8	38	20	0
March	23	5.1	36	10	35	20	0
April	6	4.5	37	16	24	24	0
Ayres Island							
November	1	2.0	50	50	0	0	0
December	No observations		--	--	--	--	--
January	2	4.0	50	0	25	0	25
February	1	2.0	50	50	0	0	0
March	18	2.2	50	50	0	0	0
April	11	3.0	8	24	34	34	0

always departed immediately after the family. Although the family tended to separate itself from the other flock members, it was observed mingling with a group of 18 whooping cranes.

On 2 days, groups of sandhills (6-14, and 3) rested on the shoreline in close proximity to whooping cranes. On both days, 2-year-old whooping cranes pecked at sandhills. Although whooping cranes and sandhills have been observed together on burn and salt-marsh areas, this is only the 2nd time the 2 species were observed together on the bay shoreline at ANWR.

From 30 November to 11 December flocks were usually along the shore when observations began. Small groups, apparently independent of each other, arrived throughout the day flying or walking from the direction of the burn. However, unknown disturbances on the burn precipitated the arrival of large numbers of cranes. Departures from the shoreline by 1 group often triggered the departure of other small groups, occasionally leaving the shoreline devoid of birds for as long as 1.5 hours.

On 12 December 1980 the use of Egg Point-BMB shoreline declined drastically. Similarly, few birds were seen arriving at the burn. After 15 December 1980, except for an unbanded pair at Egg Point, whoopers were not observed along the shoreline (Fig. 2).

Three Islands.--On 3 December, 4 cranes left the flock at Egg Point-BMB and flew northwest to a nearby area known as Three Islands. Throughout the rest of the month a flock ranging from 2-13 birds frequented this area. Initially the flock was composed of 4 birds: 2 unbanded, a 3-year-old and a 2-year-old (Table 2). The 3-year-old was always accompanied by an unbanded bird and they were observed unison calling.

Flock size increase at Three Islands coincided with the decline in bird numbers at Egg Point-BMB. A 3-year-old and a 2nd unbanded bird joined the flock; however, their movements were usually independent of the rest of the flock. Other banded subadults that previously had been observed in the Egg Point flock joined the Three Island flock, usually for 0.5-3 hours. On 13 December, 12 whoopers roosted at Three Islands but they departed at sunrise.

In January there were large subadult flocks on the refuge at the Three Islands area of St. Charles Bay, Dunham Bay, and Sundown Bay. At Three Islands the flock composition had shifted to all 3-year-olds and unbanded birds (Table 1). The 2-year-old that had been observed with an unbanded bird during December had now joined the Sundown Bay flock. This 2-year-old rejoined the Three Island flock once in January and once in February.

Throughout January, the Three Island area fluctuated between 1 large flock of 7, and 2 flocks of 5 and 2. The flock of 5 included two 3-year-olds and 3 unbanded birds. This group regularly used the nearby burn. They were observed feeding along Egg Point-BMB shoreline, the north shore of BMB, and north from Three Islands to Little Devil Bayou. Typically this flock joined the 3-year-old and an unbanded bird who frequented the area from Three Islands north to Little Devil Bayou. Within this flock there were frequent aggressive encounters. One 3-year-old was the object of most aggressive attacks. This bird was chased (ground and air) throughout the month by 1 or 2 unbanded flock members. All flock members unison called often.

In late January, the Three Island flocks began to break up. The flock with the 3-year-old and an unbanded bird were observed once at Dunham Bay with a 2-year-old and another unbanded bird. On another occasion this pair joined the large flock in Sundown Bay but later flew back to Three Islands. In February, this pair was no longer seen in St. Charles Bay. It appears that the 3-year-old, believed to be a male, and an unbanded bird set up a territory on Ayres Island during February. Throughout March this 3-year-old was observed aerially pursuing birds from Ayres Island over to adjoining Roddy Island.

The other flock of 5 was last seen the 1st week of February. On 14 February, 1 of the 3-year-old members and an unbanded bird were joined on the north shore of BMB by 3 birds including 2 from the Sundown Bay flock. Banded subadults were last observed at Three Islands on 16 February. Two 3-year-olds that had been regular Three Island flock members were not seen again during the remaining season (Table 2).

Egg Point.--The unbanded pair was observed throughout the season in the Egg Point-BMB area. In January a 3-year-old and unbanded bird were pursued by the Egg Point male until the 2 left the area. Later in January, the flock of 5 from Three Islands arrived at Egg Point from the burn and were pursued to Three Islands by this same male. In February, 3 birds including 1 from the Sundown Bay flock landed on the Egg Point-BMB shore and were immediately chased off by the pair. Beginning in mid-February only this unbanded pair and sometimes a single unbanded bird were observed in St. Charles Bay.

Dunham Bay.--During January there were 1-2 flocks of subadults in Dunham Bay. One flock utilized the far northern end of the bay while the other utilized the western shore. Although Dunham is not a deep bay, the western shore flock did not traverse the width of the bay on foot, but fed along the western shore. Throughout the season the western shore flock was usually observed at south Dunham Bay across from Grass Island (Fig. 1).

Sometimes the 2 flocks in Dunham Bay were geographically distinct and did not interact. However, at other times members of the 2 groups met on the western shore and fed together. As many as 13 birds were together. Large group flight movements were never observed. Birds arrived and departed alone or with 1-3 other birds.

Five banded subadults used Dunham Bay regularly during January: a 3-year-old, two 2-year-olds, and two 1-year-olds. A 3-year-old and a 2-year-old from other flocks were each observed in the bay with banded subadults on 1 occasion in January.

The northern flock varied in size from 2-10 members. The 3-year-old and an unbanded bird were members of this northern flock only during January. From February on, these 2 birds were observed a short distance northeast of Dunham Bay, along the GIW. The two 2-year-olds joined both the northern and western shore flocks during January. In February, however, these 2-year-olds joined the Sundown Bay flock. One to 5 unbanded birds were observed in the northern flock, including a pair from the east side of the bay. This pair never showed signs of territoriality while at the northern end.

Two 1-year-olds and an unbanded bird made up the core of the western shore flock. This trio was always observed together, but they were often joined by other birds. Frequently in January,

Table 2. Number of sightings per month by location for banded cranes at ANWR from November 1980 to April 1981.

	Nov	Dec	Jan	Feb	Mar	Apr
1977 Banded						
R-G[a]						
Dunham Bay	2					
Egg Point	1	5	1			
Three Islands		1	9	1		
R-R[b]						
Egg Point		3	1	1		
Sundown Bay				1		
Three Islands		8	9	2		
R-W						
Dunham Bay	1					
Egg Point		6				
San Jose Island			1		1	
R-N						
Matagorda Island		1			1	
W-R						
Ayres and Roddy Islands	1			1	16	5
Dunham Bay			1			
Egg Point		5				
Sundown Bay			1			
Three Islands		7	7			
B-R						
Bludworth Island				3	1	
Dunham Bay			4			
Egg Point		6	1			
Sundown Bay					1	
Slough west of Sundown Bay				1	9	7
Three Islands		1				
G-R						
Ayres and Roddy Islands					1	5
Dunham Bay	2					
Egg Point	1	5				
Redfish Slough			1			
Sundown Bay			9	5	8	5
Three Islands		1				
1978 Banded						
RWR-O						
Ayres and Roddy Islands						6
Egg Point	1	8		2		
Sundown Bay			12	5	3	
N-RWR						
Ayres and Roddy Islands			1		1	6
Dunham Bay	1		7			
1978 Banded						
N-RWR (continued)						
Egg Point	1	5				
Sundown Bay			2	6	16	2
Three Islands		2				
N-W						
Ayres and Roddy Islands			1			
Dunham Bay			1			
Egg Point		4				
Rattlesnake Island					5	2
Sundown Bay			9	4		
Three Islands		6	1	1		
S[c]						
Dunham Bay			6			
Sundown Bay			1	2		
RWR-B						
Dunham Bay	1					
Egg Point	1	1				
Sundown Bay	1		12	7	18	3
Bludworth Island						1
1979 Banded						
BWB-G/R						
Bludworth Island						1
Dunham Bay	1					
Egg Point	1	2				
Sundown Bay			12	7	18	3
R/W-BWB						
Dunham Bay	1		8	2	11	10
Egg Point		8				
Three Islands		1				
R-BWB						
Z Matagorda Island		1	1		1	
BWB-R						
Dunham Bay	1		8	2	11	10
Egg Point		8				
Sundown Bay	1					
Three Islands		1				
BWB-R/W						
Ayres and Roddy Islands						8
Dunham Bay				1		
Egg Point	1	8		2		
Sundown Bay			11	6	2	
Three Islands		1		1		

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[a] Color codes for left-right leg bands. Bird R-G not seen after 6 February 1981.

[b] R-R not seen after 16 February 1981.

[c] This bird lost its color band and only retains an aluminum band. S not seen after 23 February 1981.

2 unbanded birds that are believed to be a newly formed pair, flew over from Grass Island and joined the trio to feed and rest. Upon arrival there were often threat displays; however, physical aggression was never observed between the trio and this pair. During January the trio was also joined by the two 2-year-olds and 1-2 unbanded birds. On 3 days, the unbanded chick that had frequented Egg Point during December was in Dunham Bay with its parents. This time the family was accompanied by 1 of the 2-year-olds. The family and the 2-year-old fed with both flocks.

February and March behavioral observations in Dunham Bay were restricted to only 2 days each month. Once in February and again in March the unbanded pair from Grass Island flew over to feed and rest with the trio on the western shore and in the bordering salt marsh. A single unbanded bird attempted to feed with the trio 1 day in February. The latter bird was repeatedly chased and pursued by the unbanded trio member. This was the only time aerial pursuit was observed in Dunham Bay.

Except for the 2 times that they were joined by the unbanded pair from Grass Island, the trio was the only flock sighted in Dunham Bay from February through April. The trio was usually observed along the western shoreline and marshland across from Grass Island. On 4 occasions, however, the trio was observed feeding in the marsh on the eastern side of Dunham Bay near the GIW. The trio was last observed in Dunham Bay on 16 April. We believe that they migrated shortly after this sighting.

In Dunham Bay, territorial aggression by pairs towards the flock was observed only at the southern end of the bay. There an unbanded pair defended a territory on the western shore, just south of Grass Island. Territorial encounters involved a unison or guard call by the pair followed by the male flying north and landing near the flock. The aggressive displays caused the flock members to immediately exhibit submissive postures or flight behavior.

Sundown Bay.--Sundown Bay had the largest flocks and all 3 subadult age classes were present from January through the 1st week of April (Table 1). In January flocks ranged from 3-13 birds. Typically half of these birds were unbanded. Although at times unbanded pairs were flock members, the majority of the unbanded members were not paired. Among the 3-year-olds only 1 joined the Sundown Bay flock for the remaining winter. Two other 3-year-olds joined the Sundown Bay flock for 1 day each. The 2-year-olds, however, were well represented with at least 3 out of a possible 5 in that age class observed as flock members on 7 occasions in January. Two 1-year-olds were flock members throughout January.

Within the flock there was a tendency for certain birds to feed, rest, and depart together. A trio that included a 2- and a 1-year-old, and an unbanded bird were always together throughout the remaining season. During January and February a 3-, a 2-, and a 1-year-old, and an unbanded bird were usually together but were often joined by another 2-year-old and 1-2 unbanded birds.

Mid-January was the only time when 2 subadult flocks were observed in the bay. On 3 occasions there was a flock at the southern end of the bay mingling with some tolerant unbanded pairs, while simultaneously another flock was farther north in the usual area. Flocks were observed at the southern end of the bay 4 times in January, but the rest of the season the flocks always utilized an area in the central part of Sundown Bay (Fig. 1). This central area was unique from all other flock areas previously mentioned because it was limited on both sides by aggressive territorial pairs. The flocks fed along the western shore and across the shallow bay to the western shore of Sundown Island. The flock usually preferred to feed and rest from mid-bay to the western shore. This location provided a maximum distance from boat traffic along the GIW.

Peak flock size was reached in Sundown Bay in February. Flocks ranged from 3-15 with as many as 8 banded subadults observed at 1 time. The two 2-year-olds that had been frequenting Dunham Bay joined the Sundown Bay flock at the end of January. On 1 occasion all 5 of the 2-year-old age class were in the Sundown Bay flock. The 3-year-old and two 1-year-olds continued as flock members throughout this month. One of the 2-year-olds from Dunham Bay joined the Sundown Bay flock until the flock split up the 1st week of April. Although it interacted with the whole flock it tended to feed and rest near the trio. However, the 2-year-old trio member pecked and chased (ground and air) this new flock member during February and again in March.

During the last 3rd of February, two 2-year-olds left the Sundown Bay flock. One was a 2-year-old that had just recently left Dunham Bay. After 23 February this bird was no longer sighted with any of the flocks on the refuge (Table 2). The second 2-year-old that left the Sundown Bay flock had been accompanied off and on since December by an unbanded bird. Throughout March and into the 1st week of April this 2-year-old was sighted with an unbanded bird in the area of Rattlesnake Island, just east of Ayres Island.

In March the Sundown Bay flock size decreased to 5-6 as the cranes began to spend more time in the salt-marsh vegetation. The trio with a 2- and a 1-year-old, and an unbanded bird remained at Sundown and were joined by the 2-year-old from Dunham Bay and an unbanded bird. The 5 were usually in close proximity to each other; however, the trio continued to fly in and out of the bordering salt marsh independent of the other 2 birds.

A 2-year-old and a 1-year-old were last observed in Sundown Bay 9 March. A few days after their disappearance, the 3-year-old that had usually accompanied these 2 birds also left the flock. Ten days later these 3 birds were observed in northern Sundown Bay about 1 km from the Sundown Bay flock. The birds were feeding in the bay with the 3-year-old and unbanded bird from Ayres Island. When the 5 birds were chased by 2 territorial males, the 3-year-old and 2-year-old flew south to rejoin the Sundown flock. The 3-year-old fed and rested several 100 m from the flock the rest of the day and successfully reintegrated back into the flock by the next day. However, the 2-year-old attempted to feed near the flock and was aerially pursued by the aggressive 2-year-old trio member. The 2-year-old left and was not sighted again until 1 April at Ayres Island in the company of the 1-year-old former Sundown Bay flock member.

Dispersion of the Sundown Bay flock occurred during the 1st week in April. The flock had spent large amounts of time in the bordering salt marsh. On 1 occasion the trio was observed with 3 unidentified cranes in the salt marsh on the Mesquite Bay side of Bludworth Island (immediately west of Ayres Island).

On 6 April the trio was observed with the 3-year-old in the usual area of Sundown Bay. The unbanded trio member appeared very nervous and continued to make flight intention movements. At approximately 1000 hours the 1-year-old trio member suddently flew north, doubled back over the group and landed in the adjacent salt marsh. The 2-year-old member responded with 2 unison calls and immediately flew with the unbanded trio member to join the 1-year-old. The 3-year-old, however, flew northeast and appeared to land over by Ayres Island. The trio was not seen in Sundown Bay the rest of the day although the area was checked for the next 4 hours. Two days later at 0715 hours the trio was observed by personnel at Quivera National Wildlife Refuge in central Kansas. These birds may have arrived the night before because they departed 3 hours after they were sighted (Quivera NWR files).

Territorial aggression towards flock members from the males of the adjacent northern and southern territories was observed throughout the 1981 field season. In January, territorial aggression was observed on 6 of 11 observation days. In February and March territorial aggression was observed on 4 of 5 and 13 of 17 observation days, respectively. These aggression bouts usually occurred 1-3 times during an observational period. On 24 March the territorial male to the north chased a flock at 6 different times. During the final chasing sequence the flock flew into the salt marsh.

The intraflock aggression usually consisted of the territorial male flying in and continually chasing flock members. High bows, wing shake bows, adornment walking, head shaking, and displacement preening displays were also observed. Aerial pursuits of flock members were rare. On some occasions chasing bouts caused flock members to depart from the bay. Usually the flock members either walked quickly exhibiting submissive postures or flew a short way into the salt marsh. Except for a few occasions when stationary adornment display was observed, flock members always responded to territorial males with avoidance or submissive behaviors.

Ayres Island.--Observations at Ayres and adjoining Roddy Islands proved difficult throughout the season because the cranes usually preferred the inland marsh areas more than the shoreline. In January, observations were limited to 4 incidental sightings of the unbanded chick, its parents, and sometimes the 2-year-old from Dunham Bay. In February and March the 3-year-old and an unbanded bird from Three Islands maintained a territory at the south end of Ayres by Wynne's Cut. In March, unidentifiable groups of 3 and some solitary birds were observed on the marsh.

On 1 April the 2- and 1-year-olds that had been Sundown Bay flock members until mid-March were located at the southern end of Ayres in the 3-year-old's territory. A few days later the 2-year-old from Sundown Bay joined them. These 3 birds were observed 10 April feeding with the territorial 3-year-old and the unbanded bird. Shortly after the latter sighting the 3-year-old and the unbanded bird apparently migrated. From 14-16 April the two 2-year-olds and the 1-year-old were observed at the southern end of Ayres with the 3-year-old from the Sundown Bay flock. Thereafter until 25 April only 2 unidentifiable birds were sighted in the area. On 25 and 28 April the 3-year-old and the 1-year-old were located together at the north end of Ayres Island. We believe they migrated shortly thereafter.

CONCLUSIONS

Subadult flocks occupy the same kind of habitat as paired cranes. However, subadult flocks principally utilize areas undefended by pairs. Although suitable habitat formerly occupied by pairs was available, it was ignored by the subadults. Instead subadults have preferred traditional sites, at least since 1976. Some paired cranes will frequently join subadult flocks for a few hours at a time.

The gregarious nature of subadult whooping cranes is evidenced by the fact that lone subadults are seldom observed whereas solitary unbanded birds are often observed. There is a tendency for certain birds to associate with each other over long periods of time. Even in large aggregations these social bonds were detected when birds consistently arrived, fed, rested, and departed together.

High-intensity aggression such as bill sparring, charging, pecking, and aerial pursuit was minimal among flock members. The 2 subadults that were aerially pursued by another flock member continued to stay with their flocks. This lack of aggression among flock members may be related to the gregarious nature of the birds and to the apparent abundance of food resources.

Fluctuation in flock size and age class appears to be a result of the seasonal availability of food on the marsh and pair bonding. When the whooping cranes arrive in early fall, seasonal high tides have often carried blue crabs into the sloughs and inland salt-marsh ponds. Invertebrates such as crabs and insects are also more abundant during this warmer weather. Thus, in early fall and again in spring the cranes tend to exploit the salt marsh and as a result are not as concentrated along bay shorelines.

In past years, large aggregations of subadult and unpaired adult cranes have been observed during the early fall exploiting unusual food concentrations of blue crabs and snails. Large groups have also been associated with burns in past years. The appearance of large flocks of subadults in St. Charles Bay this past season was most likely due to the bay's proximity to the controlled burn. Aggregations in St. Charles Bay and on the burn were temporary and dispersion of whoopers occurred after the apparent depletion of food resources on the burn.

The possibility of pair bonding among 2nd- and 3rd-year birds may also be responsible for the change in age classes within the flocks. In 1980-81 most 3-year-olds joined flocks at the beginning of the season; however, by mid-February only one 3-year-old was still associated with a large subadult flock. Among 2-year-olds a similar pattern was observed when 2 in that age class left the flocks. It is too early to analyze this pairing process because these subadults have only been accompanied by unbanded birds that cannot be positively identified. It is also unknown what role subadult flocks play in pair formation.

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WHOOPING CRANE PRODUCTION AT THE PATUXENT WILDLIFE RESEARCH CENTER, 1967-1981

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Abstract: Between 1967 and 1974, 50 whooping crane (*Grus americana*) eggs were collected from wild nests in Wood Buffalo National Park, Canada, and hatched at the Patuxent Wildlife Research Center in Laurel, Maryland, in order to establish a captive flock. The birds hatched from these eggs formed the nucleus of the Patuxent flock. The 1st breeding at Patuxent occurred in 1975, when 1 female laid 3 eggs. Since that time several additional females have become productive. From 91 eggs produced between 1975 and 1981, 9 whooping crane chicks have been reared in captivity, and 3 have been successfully cross-fostered to wild greater sandhill cranes (*G. canadensis tabida*) in Idaho. Many of the problems encountered in propagating whooping cranes have been magnified due to the small size of the captive flock, and the absence of normal copulatory behavior in adults. Current research aimed at rectifying these problems centers on rearing chicks with surrogate sandhill crane parents, and on improving the reproductive performance of breeding pairs.

By late in the 19th century, the whooping crane was uncommon and its numbers rapidly declining. This decline continued into the early 20th century, and by 1937 only 2 small breeding populations remained--a sedentary population in southwestern Louisiana, and a migratory population that wintered along the Texas coast on the newly established Aransas National Wildlife Refuge. The demise of the Louisiana population in 1948, and the extremely slow growth of the migratory population between 1937 and 1956, prompted concerned biologists to propose augmenting the wild population through captive propagation. This proposal generated considerable controversy at that time (Erickson 1976) although it is now generally recognized that captive propagation can effectively complement conventional conservation efforts. After 5 years of preliminary studies on sandhill cranes the Canadian Wildlife Service (CWS) and U.S. Fish and Wildlife Service (USFWS) agreed in 1966 to collect eggs from breeding pairs in Wood Buffalo National Park (WBNP), Canada, in order to establish a captive flock at Patuxent Wildlife Research Center (PWRC) in Laurel, Maryland. The principal goals of this program have been to maintain birds in captivity to preclude extinction of the species if there were some catastrophic loss to the wild populations, to foster basic research, and to produce offspring for release into the wild (Erickson 1968, 1975, Kepler 1978).

The purpose of this paper is to provide a summary of whooping crane production at the PWRC and an overview of current problems and research directions. Various aspects of sandhill crane and whooping crane propagation at PWRC have been discussed previously by Erickson (1975, 1976), Carpenter (1977, 1979), Carpenter et al. (1976), Kepler (1976, 1978), Derrickson and Carpenter (1981), and Erickson and Derrickson (1981).

ESTABLISHMENT OF THE CAPTIVE FLOCK

Following the discovery of the breeding grounds in WBNP in 1954, the CWS initiated a program of periodic surveys to identify nest locations, nesting chronology, productivity, and other aspects of breeding biology (Novakowski 1966, Kuyt 1976a, b). During 1 of these surveys in September 1964 a breeding pair was observed with a single chick with a severely injured wing. This bird--a male eventually named CANUS--was subsequently captured and transferred to Monte Vista National Wildlife Refuge in Colorado where preliminary studies on sandhill crane propagation were being conducted by the USFWS (Novakowski 1965). CANUS and the experimental sandhill flock were transferred to permanent facilities at PWRC after the Endangered Species Research Program was established by the USFWS in 1966.

Additional whooping cranes were obtained for the captive flock by removing eggs from wild nests in WBNP after 16-29 days of natural incubation ($\bar{x} = 22.9$, SD = 3.2, N = 40) had been completed. The eggs were then placed in an incubator suitcase (Erickson 1981) and transported to PWRC where the eggs were artificially incubated, and the chicks were hand-reared. The egg collections and subsequent propagation efforts at PWRC have been previously described (Erickson 1975, 1976, Kuyt 1976b, Kepler 1978).

Table 1. Fate of whooping crane eggs transferred from wild nests in WBNP, Canada, to PWRC.

Year	Number of eggs			Number of birds lost	
	Taken	Fertile	Hatched[a]	1st 6 months	Adult plumage
1967	6	6	6	2	2
1968	10[b]	10	10	3	2
1969	10	8	7	2	2
1971	11	10	9	6	2
1974	13	11	9	5	2
Total	50	45	41	18	10

[a] Unhatched eggs were opened and examined following full-term incubation: 5 eggs (69-9, 69-10, 71-12, 74-6, 74-8) contained no detectable embryo; 3 eggs (69-12, 71-5, 74-1) contained well developed embryos which died during late incubation; and 1 egg (74-12) contained a normal embryo which died soon after pipping.

[b] Includes 1 wet and newly hatched chick which was removed from the nest (instead of an egg) to avoid chilling.

Between 1967 and 1974, 50 eggs were taken from the wild (Table 1). Forty-five (90%) of these eggs were fertile and 41 (91%) hatched. Including CANUS, there are now 13 birds of Canadian origin in the Patuxent flock, representing 10 of 19 known WBNP territories. Eleven of these birds are currently located at PWRC and 2 are on loan to the San Antonio Zoo in Texas.

Wild eggs have been cross-fostered to pairs of greater sandhill cranes at Grays Lake National Wildlife Refuge in southeastern Idaho each year since 1975 (Drewien and Bizeau 1978) in order to establish a 2nd migratory flock of whooping cranes. The fertility and hatchability of these cross-fostered eggs have been similar to that recorded while establishing the captive flock (R. C. Drewien pers. comm.). As noted by Erickson (1976) and Kuyt (1976a), egg removals from WBNP have not adversely affected the wild population. Between 1967 and 1989, the Wood Buffalo population has increased from 48 to 78 and the number of breeding pairs has increased from 9 to 19. The cross-fostered whooping crane population, which migrates between Idaho and New Mexico, now numbers 15-17 birds.

Additional whooping crane eggs and chicks were obtained from the San Anontio Zoo, but only 1 bird, a female named TEX, survives. TEX was hatched in 1967 and transferred to PWRC when 3.5 weeks old. Since 1976, she has been on breeding loan to the International Crane Foundation (ICF), Baraboo, Wisconsin. Another female chick, hatched in 1979, was transferred to PWRC but died soon after arrival as a result of internal injuries believed to have occurred during shipment. Nine of 19 (47%) whooping crane eggs received from the San Antonio Zoo between 1968 and 1979 were fertile, but only 1 egg hatched (Table 2). The small (96-g) spraddle-legged chick was unable to stand, and died 2 days after hatching.

WHOOPING CRANE PRODUCTION AT PWRC

The initial concern of the captive program was hatching, housing, and rearing the young cranes. Whooping cranes have generally proved to be more difficult to raise in captivity than sandhill cranes. Although many of the propagation techniques originally developed for sandhills have been directly applied to whooping cranes, a number of procedural modifications have been required (Kepler 1978, Erickson and Derrickson 1981). As is true of captive sandhills at PWRC (Carpenter et al. 1976), the majority (68.3%) of whooping crane mortalities have involved downy young. Bacterial infections, parasitic diseases, and anatomical abnormalities (principally leg and toe problems) have accounted for most losses (Carpenter and Derrickson, this proceedings).

Procedures originally used in hatching and rearing whooping cranes at PWRC have been previously discussed by Erickson (1975) and Kepler (1978). Most chicks were initially raised indoors either individually or in small groups during the period of most rapid growth and development. The young birds were subsequently moved to outdoor juvenile quarters, and then to subadult community

Table 2. Whooping crane eggs transferred from San Antonio Zoo to PWRC.

Year	Pair	No. eggs	No. fertile	No. hatched
1968	Crip x Rosie	3	0	0
1969	Crip x Rosie	4	1	0
1970	Crip x Rosie	7	5	1
1978	Crip x Ektu[a]	1	1	0
1979	Crip x Ektu	4	2	0
Total		19	9	1

[a] Following the death of Rosie in 1971, Crip remained unpaired until an 8-year-old female of Canadian origin (Ektu, R18) was placed on breeding loan by PWRC in 1976.

Table 3. Age of 1st breeding of 8 captive whooping crane females.

Female	Year hatched	Year 1st laid	Age (years)
R11 (LL)	1968	1975	7
R10 (UL)	1968	1977	9
R8 (UR)	1968	1977	9
R15 (60A)	1971	1976	5
R17 (G2)	1971	1979	8
B1 (I2)[a]	1974	1981	6
R18 (EK2)[b]	1967	1978	11
R20 (TEX)[c]	1967	1977	10

[a] Female died egg-bound with 1st egg (24 May 1981).

[b] Laid 1st egg while on loan to the San Antonio Zoo, Texas.

[c] Laid 1st egg while on loan to the International Crane Foundation, Baraboo, Wisconsin.

pens. Individuals were transferred from these enclosures to visually isolated breeding pens (17 x 17 m or larger) after each selected a mate or was force-paired (Kepler 1978).

Age of 1st Breeding

Wild whooping cranes have not been marked until recently (Kuyt 1979a, b); consequently, many aspects of their life history and population biology remain unknown. Although it is clear that adults are potentially long-lived, and that sexual maturity is delayed, the average age of 1st breeding is unknown in the wild. During the 1980 breeding season, two 3-year-old whooping cranes were observed as members of breeding pairs in WBNP (E. Kuyt pers. comm.). This suggests that sexual maturity may normally be achieved considerably earlier than originally believed.

At Patuxent, we have not regularly obtained semen from males until their 4th year, and, although 1 female produced eggs at age 5, most females have not laid until considerably older (Table 3). A number of factors have been identified as responsible for delaying reproduction in the captive flock, including rearing conditions, dominance relationships, sexual compatibility, inadequate pen size, and stress associated with handling and disturbance (Kepler 1976, 1978, Dereickson unpubl. data).

Artificial Insemination

Although our productive pairs of whooping cranes exhibit normal precopulatory behavior, and males regularly attempt to mount their mates, successful copulations have not been observed. Consequently, to obtain fertile eggs, females are artificially inseminated using a variation of the massage technique (Archibald 1974, Gee and Temple 1978). Because artificial insemination (AI) nesessarily requires repeated capture and handling, there is always a possibility that reproductive activities may be adversely affected as a result of injury or stress. For this reason, we no longer inseminate pairs until poor reproductive performance has been confirmed during initial breeding attempts. Furthermore, in order to condition pairs to the manipulations associated with this procedure, we normally begin collecting semen from the males and handling the females well in advance of egg laying. Females are inseminated as soon as their pubic terminals begin to separate and AI continues until laying ceases. During this entire period we routinely attempt to AI females 3 times per week and immediately after each oviposition.

We have not been able to achieve a consistent, high rate of fertility even though fertile whooping crane eggs are obtained each year using AI. During the past 6 breeding seasons, overall fertility has ranged from 33 to 83% (average 64%), while the fertility of individual females has ranged from 0 to 100%. Available evidence suggests that these annual and individual variations in fertility result from a variety of factors, such as the quality and quantity of inseminated semen, the site of insemination (cloaca vs. oviduct), and the timing of insemination in relation to oviposition. Although additional refinements in AI procedures may substantially improve fertility in the future, fertilization currently remains the biggest bottleneck in propagating large numbers of whooping cranes in captivity.

Manipulation of Egg Production

Like other cranes, whooping cranes are indeterminate layers, and will renest if their 1st clutch is removed or destroyed before midincubation. We routinely collect all eggs as they are laid in order to stimulate renesting and ensure maximum production. Using this procedure, our productive females typically lay several clutches each season at intervals ranging from 6 to 20 days ($\bar{x}$ = 11.9, SD = 4.9, N = 35). Clutch size in captivity has averaged 1.7 (SD = 0.6, range = 1-4, N = 53), while egg production per female has ranged from 1 to 11 eggs per year ($\bar{x}$ = 51, SD = 3.0, N = 18).

At Patuxent, whooping cranes normally begin laying between late March and mid-April, and cease laying with the onset of hot weather in late May or early June (Fig. 1). We regularly expose several of our breeding pairs to artificial photoperiods in order to extend their breeding season. As previously noted by Kepler (1978), photostimulated pairs tend to lay earlier in the spring and consequently have more time to produce additional clutches before hot weather halts egg production. During the next few years, we will be conducting a number of experiments on pairs of sandhill cranes to determine the extent to which production can be enhanced and manipulated with photostimulation. Results of these experiments will hopefully allow us to exert greater control over whooping crane production.

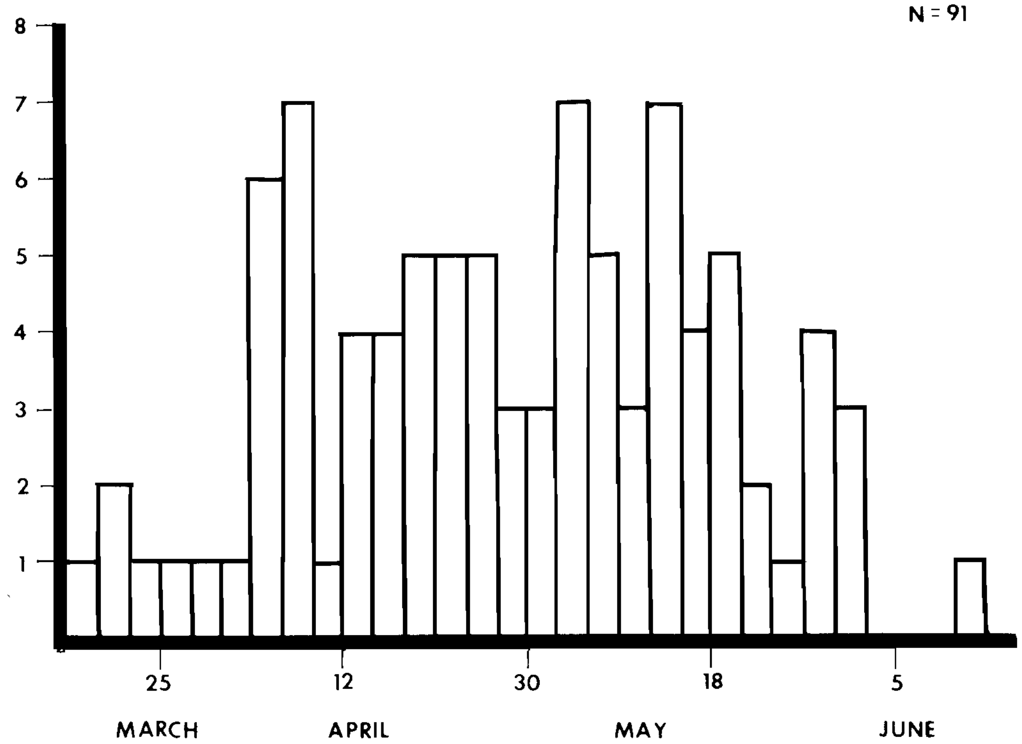

Fig. 1. [illegible] whooping cranes at PWRC.

Productivity of the Captive Flock

Eggs were 1st produced at Patuxent in 1975, when 1 female laid 3 eggs. Since that time, several additional females have become productive, and from 5 to 23 eggs have been laid annually. Over the past 6 years (1975-1981) the captive flock has produced a total of 91 eggs (Table 4).

Fifty-three eggs (58%) have been retained at Patuxent, either because they were known to be infertile or because they were laid too early to be cross-fostered to wild sandhill cranes at Grays Lake National Wildlife Refuge (GLNWR) in Idaho. Of the 53, 32 (60%) were fertile, 23 (72%) hatched, and 10 (43%) chicks were successfully reared to fledging. Nine of these 10 chicks still survive.

Between 1975 and 1977, eggs that were retained at Patuxent were machine incubated, and the chicks that hatched were hand-raised using conventional rearing procedures (Erickson 1975, Kepler 1978). Since 1978, however, whooping crane eggs have been incubated and hatched, and the chicks subsequently reared by selected pairs of captive sandhill cranes. These young whooping cranes have been allowed to remain with their foster parents for 4-5 months before being moved to large (16 X 33 m) covered flight pens. Unlike older birds in the PWRC flock, which were rendered flightless by pinioning or tenotomy, these birds are being maintained full-winged. A new complex of large (15 x 30 m) covered breeding enclosures, specifically designed to accommodate these "parent-reared" birds, is currently being constructed.

Table 4. Summary of whooping crane production at Patuxent.

			Eggs retained at Patuxent				Eggs transferred to Grays Lake			
Year	No. of females laying	Total no. eggs	No.	No.[a] fertile	No. hatched	No. surviving	No.	No.[b] fertile	No. hatched	No. surviving
1975[c]	1	3	3	2	1	0	0	0	0	0
1976[c]	2	5	3	1	1	1	2	1	0	0
1977[c]	4	22	8	4	3	1[d]	14	8	5	0
1978[e]	3	23	8	8	7	3	15	11	5	0
1979[f]	4	21	16	11	8	3	5	4	4	2
1980[f]	2	6	4	1	0	0	2	2	2	1
1981[f]	2	11	11	5	3	1	0	0	0	0
Totals	-	91	53	32	23	9	38	-	16	3

[a] Fertility determined for unhatched eggs by examination of egg contents. Examination occurred after full-term incubation and eggs containing no detectable embryo were considered infertile; therefore, the number of fertile eggs is considered to be a minimum estimate.

[b] Fertility estimates for 1976 and 1977 are based on results of pretransfer candling. In 1977, of the 14 eggs transferred, 3 were deserted after a snowstorm, 1 was destroyed by a predator, 5 were infertile or addled, and 5 hatched. Fertility estimate for 1978 was derived after examination of unhatched eggs. In both 1979 and 1980, fertility was determined by flotation before hatching.

[c] All eggs artificially incubated full term or until transfer; all chicks hatched were hand-raised at PWRC.

[d] Two chicks were successfully raised, but 1 (female 812/8351) subsequently died at 4 years of age.

[e] All eggs retained at PWRC were incubated and hatched under sandhill cranes, all eggs transferred to Grays Lake were artificially incubated until transferred to the wild.

[f] All eggs incubated under sandhill cranes; chicks hatched at PWRC were reared by sandhill crane foster-parents.

Cross-fostering Eggs to the Wild

Whooping crane eggs have been routinely cross-fostered to wild pairs of sandhill cranes at GLNWR since 1976 because the principal goal of Patuxent's breeding program is to establish or bolster wild populations with offspring from the captive flock. Thirty-eight eggs have been transferred: 2 in 1976, 14 in 1977, 15 in 1978, 5 in 1979, and 2 in 1980 (Table 4).

Our original attempts to cross-foster captive-produced eggs to the wild were unsuccessful. Of the 31 eggs transferred between 1976 and 1978, only 10 (32%) hatched, and none of the chicks survived. By 1978, we realized that the poor hatchability of eggs resulted from (1) the transfer of infertile eggs, and (2) the artificial incubation of eggs before shipment. For reasons that are still unclear, artificially incubated eggs produced weak embryos and chicks that died either late in incubation or soon after hatching (Erickson and Derrickson 1981). As a result, in 1979 and 1980, all whooping crane eggs destined for Grays Lake were incubated under sandhill cranes at Patuxent before their transfer, and only eggs that contained viable embryos, as determined by flotation rather than by candling, were shipped. In both years, hatchability and survivorship equalled that observed in eggs and chicks derived from the wild Wood Buffalo population. Thus far, 3 chicks of PWRC origin have been successfully fledged at Grays Lake (2 in 1979, 1 in 1980), and all 3 birds still survive (R. C. Drewien pers. comm.).

DISCUSSION

Over the past 15 years, we have learned a great deal about rearing, maintaining, and breeding whooping cranes in captivity. Most of our propagation and husbandry procedures have been extensively modified, and can now be considered to be in the refinement rather than developmental stage. Although the PWRC program has demonstrated that sustained propagation in captivity is feasible, and that offspring from the captive flock can be returned to the wild, a number of important problems still need to be resolved if the captive flock is to play an important role in the whooping cranes' recovery. These problems and potential solutions are discussed briefly below.

Size of the Captive Flock

Due to the substantial mortality of chicks during the early years of our program, and the delayed reproduction of adults, the captive flock has never been very large. The small size of the captive flock has already adversely affected our breeding program by placing severe constraints on our ability to form socially and sexually compatible pairs. Obviously, the size and genetic representation of the captive flock needs to be increased as soon as possible (Table 5). We believe that this could be readily accomplished by securing 2-3 eggs per year from territories in WBNP that are currently unrepresented in the captive flock. Such a program would not adversely affect the Grays Lake cross-fostering program, yet would greatly enhance future behavioral, demographic, and genetic management of the captive flock.

Artificial Insemination

Egg fertility continues to be a major obstacle in our propagation program because we must rely entirely on artificial insemination. Although many captive pairs of cranes do not copulate successfully (Archibald 1974, LaRue 1980), we are uncertain whether this results from inexperience, abnormal rearing conditions during ontogeny, the male's inability to mount and balance following tenotomy, or other inhibiting factors. However, preliminary investigations with sandhill cranes suggest that cranes reared by parents show normal copulatory behavior upon reaching sexual maturity. These results are especially encouraging when 1 considers that the fertility rate of copulating pairs of sandhill cranes at Patuxent (85-96%) normally exceeds that obtained by AI (55-80%). We are allowing selected pairs of sandhill cranes to hatch and raise our young whooping cranes.

Rearing Procedures

Whooping cranes have proved to be much more difficult to raise than sandhill cranes (Kepler 1978, Erickson and Derrickson 1981). Beginning in 1978, propagation procedures for whooping cranes were modified to exclude machine incubation and hand-rearing. Young whooping cranes hatched and reared by foster-parent pairs of sandhill cranes are much more robust and vigorous than hand-reared birds, and have not developed leg and toe abnormalities.

Table 5. Composition of the captive whooping crane flock at Patuxent.[a]

No.	Pen	Sex	Identity	Origin (wild territory or captive source - year/ sire and dam identity)
1	UL	M	R7/216	WBNP - 1969/Klewi-unnamed
2	UL	F	R10/261	WBNP - 1968/Klewi 2
3	UR	M	R14/265	WBNP - 1968/Klewi 1
4	UR	F	R8/259	WBNP - 1968/Klewi-unnamed
5	LR	M	R19/270	WBNP - 1967/Sass 2
6	LR	F	-/268	WBNP - 1967/Sass 1
7	G2	M	R21/CANUS	WBNP - 1964/Sass 3
8	G2	F	R17/432	WBNP - 1971/Klewi 1
9	H2	M	B4/253	WBNP - 1974/Nyarling 1
10	H2	F	B8/83	PWRC - 1977/270 x 429
11	I2	M	B2/254	WBNP - 1974/Klewi 3
12	BY	M	R4/262	WBNP - 1968/Klewi 6
13	10P	M	B5/391	PWRC - 1976/262 x 263
14	FP-A1	F	8251	PWRC - 1978/216 x 261
15	FP-B1	M	8253	PWRC - 1978/265 x 259
16	FP-C1	M	8256	PWRC - 1978/265 x 259
17	FP-B2	M	8403	PWRC - 1979/265 x 259
18	FP-B2	F	8401	PWRC - 1979/216 x 261
19	FP-B2	M	8402	PWRC - 1979/265 x 259
20	R5	?[b]	--	PWRC - 1981/216 x 261

[a] Three other whooping cranes are currently on breeding loan. Two are at the San Antonio Zoo (male R13/218, WBNP-1969, Klewi 5; female R6/221, WBNP-1969, Klewi 1); and 1 is at ICF (female R20/TEX, San Antonio Zoo 1967, Crip x Rosie).

[b] Probably a female.

Foster-parent rearing procedures have been modified and refined annually, and, as a result, mortality has been reduced substantially. At present, most chicks are being lost either during hatching or the 1st 5 days of life. We originally attempted to reduce mortality during this critical period through increased monitoring of hatching events and physical condition. Unfortunately, this effort proved largely counterproductive, and only increased disturbance of the surrogate parents. Preliminary experiments with sandhill cranes suggest that mortality during the aforementioned period can be reduced by removing the egg just before hatching, hatching the chick under controlled laboratory conditions, and then adopting the chick back to its surrogate parents after 5-10 days. We hope to duplicate this procedure with young whooping cranes during the 1982 breeding season.

Release Experimentation

One of the principal goals of the Patuxent program is to establish or bolster wild populations of whooping cranes with offspring from the captive flock. Eggs derived from our captive breeders have already been successfully cross-fostered to wild pairs of sandhill cranes at Grays Lake and we will continue this effort in future years. However, we are additionally testing the feasibility of releasing subadult cranes directly into the wild. Recent experimental releases of captive, parent-reared sandhill cranes into both migratory and nonmigratory populations have shown encouraging results (Drewien et al. this proceedings, Zwank and Derrickson this proceedings). We intend to continue and expand this research because these studies will provide valuable information for designing future releases for whooping cranes.

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SPERM MORPHOLOGY IN THE CRANE

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Abstract: Semen samples were collected from 11 species and 5 subspecies of male cranes in 17 time periods during May 1981. Semen samples were fixed to microscope slides and stained. Stained slides were examined microscopically for general sperm morphological studies and to determine sperm head dimensions. Photographs were taken of selected sperm and "true" sperm head area was calculated using a digitizer. Means of sperm head dimensions were calculated in order to compare these among subspecies and species of cranes. Species' and subspecies' (within these species) sperm head length, width, approximate head area, and true head area were compared. There were significant species by time interactions for all of these variables. Sperm head dimensions for most of the species were different from the red-crowned crane (*Grus japonensis*) species that was used as a comparison species because it contained the largest sample of individual birds. Sperm head widths differed less between species than did sperm head lengths. Digitized sperm head areas revealed that there were morphological differences in crane spermatozoa.

INTRODUCTION

As the number of endangered species of wild birds increases, so does the need for programs using captive propagation (Martin 1975). Successful captive propagation in cranes is accomplished by attaining the correct balance of several important factors. These factors include nutrition, photoperiod, temperature, hygiene, psychological security, proper nesting materials, and sexual maturity, all of which are important in bringing the birds into full physiological reproductive condition. Despite the effort to provide or enhance these requirements, pairs of birds in captivity still fail to reproduce (Gee and Temple 1978). A pair will often engage in all of the preliminary aspects of breeding but fail to copulate (Cade 1975, Temple and Cade 1977). As a result, artificial insemination (AI) becomes not only a helpful tool but an essential procedure for propagation of the species threatened with extinction.

AI is the introduction of semen into the female genital tract by the use of instruments (Siegmund 1967). It provides a practical way to help solve the problems of infertility in captive birds. AI is a relatively common practice in poultry and has been used successfully for many years (Burrows and Quinn 1936). However, AI must coincide with the proper health factors, sexual maturity, nutrition, and photoperiod (Skinner and Arrington 1969). AI used properly is of great importance to the poultry industry.

Only recently has AI been applied to wild birds such as ducks and geese (Johnson 1954, Watanabe 1957, Kinney and Burger 1960, Lake 1962, Pingel 1972, Skinner 1974), pigeons and doves (Owen 1941), hawks (Berry 1972, Temple 1972, Corten 1973), eagles (Hamerstrom 1970, Grier 1973), and now cranes (Gee 1969, Archibald 1974, LaRue 1980, Russman unpubl. rep.). Although AI is helpful, it is really only the beginning of what must be done to aid in the successful propagation of these endangered species. The objective of this study was to survey the basic sperm morphological characteristics of several species of cranes, and to determine any similarities and differences. In performing this study a foundation will be established for future work in crane sperm morphology.

Literature Review

Sperm morphology is analyzed by classifying and characterizing normal and abnormal cell types and by measuring various dimensions of normal sperm cells (Sharlin 1976). Sperm morphology studies have been done on a variety of animals. Domestic animals such as bulls and horses have been studied by Savage et al. (1930). Spermatozoa were 1st studied quite superficially by examining the male reproductive organs, then by light-microscopy to learn their general morphology, and finally by electron microscopy to depict even more detail. In spite of these studies on sperm structure, there is still much to be learned about the true anatomy and physiology of avian spermatozoa, particularly sperm in the 15 different species of cranes.

Some of the 1st work with avian sperm was by Ballowitz in 1888 (Grigg and Hodge 1949). To better study the cell he morphologically described the sperm of domestic fowl as having 3 regions: the head, midpiece, and tail. The head was described as a long, cylindrically shaped body which

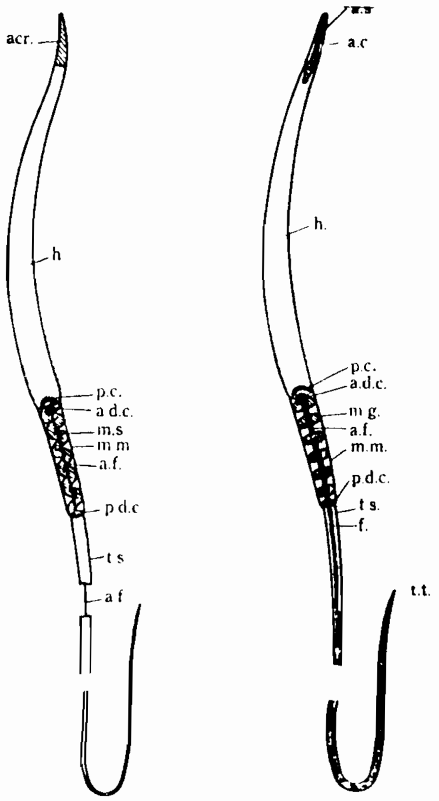

Fig. 1. Diagramatic representation of sperm morphology. On left, structural features as described by Ballowitz (1888 in Grigg and Hodge 1949). On right, structural features as determined by the electron microscope: Acr, acrosome; ac, apical cap; as, apical spine; h, head; adc, anterior distal centriole; af, axial filament; ms, mitochondrial spiral; mm, midpiece membrane; pdc, posterior centriole; mg, mitochondrial granules; f, fibrils in axial filament; and tt, tapering tip of tail (Grigg and Hodge 1949)

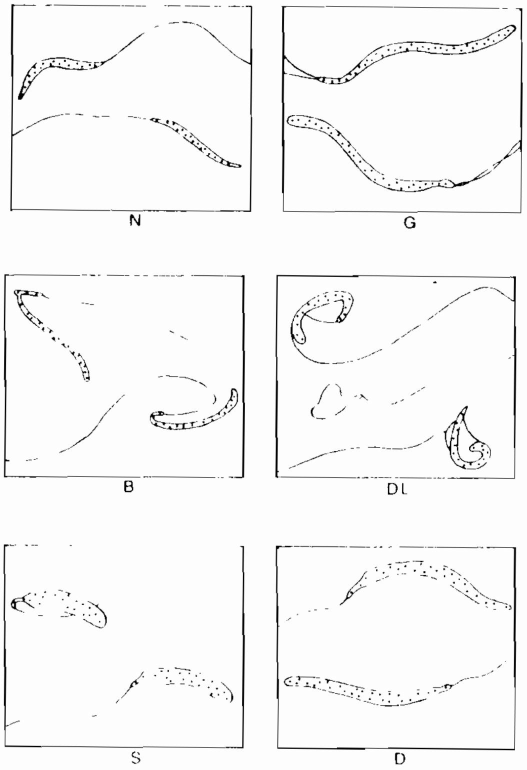

Fig. 2. Spermatozoa of the greater sandhill crane illustrating normal and abnormal forms: N, normal; B, bent; S, swollen; G, giant; DL, droplet; and D, dead (Gee and Temple 1978)

tapered at the anterior end to a small, pointed, intensely-staining apex which was later described (Grigg and Hodge 1949) as the acrosome (Fig. 1).

Size and shape of avian spermatozoa varies among different species (McFarlane 1963). Wilson (1925) has even suggested that sperm morphology may be used as a taxonomic tool to identify species of vertebrates and invertebrates. Khan and Mukherjee (1974), for example, found morphological differences in sperm head length, breadth, shape, and area among 6 strains of white leghorn cocks.

The length of avian sperm has a large range, varying from 30 to 300 μm (Sharlin et al. 1979). There is no relationship between the size of the bird and size of the sperm. McFarlane (1963) undertook a comparative survey of the entire class of avian sperm and found that some of the smaller passerines produced some of the largest sperm. Measurements of total length are difficult because the tail may break or adhere to other particles in the field of view.

The higher the taxonomic level, the greater the variation in sperm morphology. Between orders there are differences in all major components of sperm such as the acrosome, head, midpiece, and tail. Between families there are still numerous differences in structural morphology. Qualitative differences are present between genera. Only quantitative morphological differences were found between species of 1 genus (McFarlane 1963).

Sperm morphology has not been extensively studied in semen samples collected from nonpoultry, nondomestic birds (Gee and Temple 1978). Corten (1973, 1974) studied sperm morphology in the goshawk. He differentiated cell types; however, correlations were not made between these types and any other semen characteristics (Gee and Temple 1978). Bird et al. (1976) studied semen samples in kestrels and differentiated normal and abnormal spermatozoa in young birds and in the early part of the breeding season.

Gee (Gee and Temple 1978) studied sperm morphology in captive sandhill cranes at Patuxent Wildlife Research Center in Laurel, Maryland. They identified 6 cell types in live sperm samples as well as stained smears (Fig. 2A). On a slide on which 87% of the cells were alive, 57 ± 18.4% (± mean standard deviation) were normal (N) or of average size and without membrane distortions. Among the remaining live cells, 17.5 ± 9.4% were characterized as bent (Fig. 2B) because they were bent at sharp angles in the head, body, or midpiece; 6 ± 4.3% were characterized as having bodies of greater diameter(s) than the N cells; 1 ± 0.02% had more than 1 tail or bodies that were 1.5 or more times larger than the normals (G); and 5.2 ± 5% were partially or totally trapped in a spherical body (DL). The remaining cells (13%) were dead, and 11.6 ± 12.1% of these appeared swollen and slightly longer than the normal sperm cells (D); 1.5 ± 2.8% appeared abnormal and similar to the live abnormal cells (Gee and Temple 1978). These data were collected throughout the reproductive season. Gee and Temple (1978) found that these cell types appeared consistently throughout the collection period; however, there were greater numbers of the abnormal dead type of sperm early in the season just as had been found in kestrels (Bird et al. 1976).

Sharlin (1976) studied the sperm morphology of 4 species of sandhill cranes (*Grus canadensis*) at Patuxent. Sharlin (1976) obtained samples from cranes throughout an entire breeding season and measured sperm head length in each of the 4 subspecies, in order to evaluate subspecific differences and to determine whether or not sperm head length could be an appropriate index to predict fecundity in the sandhill crane (Sharlin et al. 1979). Sharlin et al. found that mean sperm head length did not vary over weeks for any subspecies. There were significant differences ($P < 0.01$) in mean sperm length between individuals within a subspecies and between subspecies ($P < 0.01$), the former difference being attributed to random sampling. Sharlin's study stimulated studies of sperm morphology in other species of cranes in order to better propagate these endangered birds; thus, the idea for this project evolved.

We are grateful to B. C. Wentworth and C. N. Graves for their advice, encouragement, and friendship. They provided assistance and equipment during field and laboratory work. We also thank G. Gee and E. Rasch for their ideas and great interest in this project. D. Gianola, R. Fernando, and B. Pudalov donated hours of time for statistical advice. A special thanks to G. W. Archibald and his hard-working staff, B. Baechler, S. Rogers, C. Baumann, L. Fields, R. Besser, and M. Putnam at the International Crane Foundation in Baraboo, Wisconsin, who helped make this study possible.

MATERIALS AND METHODS

Field and Lab Work

Semen samples were collected from 11 species (including 5 subspecies) of cranes every other morning at 0800 hours throughout an entire breeding season (beginning in February and ending in June). The crane species and subspecies involved are as follows: Red-crowned, white-naped (*G. vipio*), whooping (*G. americana*), common (*G. grus grus*), lesser sandhill (*G. c. canadensis*), greater sandhill (*G. c. tabida*), Florida sandhill (*G. c. pratensis*), sarus (*G. antigone*), Indian sarus, (*G. a. antigone*), eastern sarus (*G. a. sharpii*), demoiselle (*Anthropoides virgo*), Stanley (*A. paradisea*), brolga (*G. rubicunda*), Siberian (*G. leucogeranus*), and wattled crane (*Bugeranus carunculatus*).

Official sampling did not begin until March, however, because the male bird might not respond immediately to sexual stimulation and might even react in a negative manner to any "invasion" of his territory. For this reason AI is usually started at least 2 weeks before the expected beginning of the breeding season. This preliminary handling of the bird causes him to overcome some of his nervousness and increases the chances of obtaining a "good" sample at the beginning of the breeding season. The schedule of sampling corresponded to the artificial insemination program at the International Crane Foundation in Baraboo, Wisconsin.

The basic collection procedure described by LaRue (1980) and Russman (unpubl. rep.) was followed. The semen sample was microscopically examined in the field for sperm quantity, quality, and motility information. The remaining semen was kept in the syringe, labeled, and placed in a constant temperature thermos to prevent sperm death due to temperature shock, and to avoid any unnecessary damage from ultraviolet light. The time of the collection period varied due to weather conditions and bird cooperation; thus elapsed time between the 1st collection and the time of the 1st smear varied from 90 to 120 minutes. Smears were made following the exact sequence of collection so that each sample was treated equally. Smears were prepared as described by Sharlin (1976). The completely dried smears were then fixed in Bouin's fluid and stained, using a modification of the staining technique as described by Sharlin (1976).

Microscopic Examination

A light microscope (Zeiss Photomicroscope III) equipped with an Optivar, to obtain 1600X power, was used to observe and study the spermatozoa. A disc occular micrometer was placed inside the right eyepiece and calibrated at 1600X with a stage micrometer in order to measure the cells. Sperm head length was defined as the distance between the proximal centriole and posterior border of the acrosome. Sperm head width was defined as the maximum width of the head (1 maximum width measurement was taken for each sperm, see Fig. 3, right drawing). The spermatozoa are cylindrical when alive and flattened into a rectangle when dead. These cells were measured dead. Thus, *approximate* sperm head area was calculated as head length times head width.

True sperm head area was calculated with the use of photography. Photographs of the sperm were taken with Panatomic-X (FX 135-20) and developed as black and white prints. These prints were then taken to a Talos Coordinate Digitizer with a Magnavox Orion Microcomputer which can be used to calculate area in square inches. The sperm head area on the print was calculated by digitizing points outlining the sperm head. To correct for magnification, sperm were measured (head length and width) before they were photographed and these values were recorded. The same dimensions were also measured on the print. The area of the sperm head is basically that of a rectangle (sperm cells are flattened out when dead) or length times width. Consequently, the ratio recorded was area on print:area calculated under the microscope. In this way, a magnification difference between microscope and print could be calculated. The value per square inch obtained from the digitizer could be converted to square microns by multiplying by the correction factor of 6.4516×10^8 square microns per square inch. This product was then divided by the magnification ratio as follows in equation 1:

$$\text{Area of sperm head} = \frac{6.4516 \times 10^8\ \mu\text{m}^2/\text{square inch} \times \text{square inches computed by digitizer}}{\dfrac{\text{Length} \times \text{width of sperm head on print } (\mu\text{m})}{\text{Length} \times \text{width of sperm head in microscope } (\mu\text{m})}}$$

General morphological characteristics were also studied, such as general uniformity of size and shape, percentage of abnormal cells, and the effect of and amount of contamination in the samples. The number of sperm cells to be measured per sample was calculated in the manner of Sharlin (1976). As a result of following Sharlin's equation, 10 cells were randomly chosen and measured per slide.

Statistical Analysis

Data were collected from birds during 17 time periods in May 1981 (every other day, beginning 1 May and ending 31 May). The data set can be treated as an incomplete bird by time layout because not all birds contributed data in each collection. A collection from a particular time was represented by 10 measured sperm. Dependent variables (sperm head length, head width, approximate head area, [head length times head width] and true head area [measured by a digitizer]) were described by the mixed model:

$$Y_{ijkl} = \mu m + S_i = b_{ij} = T_k + (ST)_{ik} + e_{ijkl}$$

where Y_{ijkl} is the lth sperm measure taken at the kth time in the jth bird of the ith species or subspecies, μm is a fixed effect common to all observations, S_i is the effect of the ith species or subspecies, T_k is the fixed effect of the kth time period, $(ST)_{ik}$ is an interaction between the ith species or subspecies and the kth time period, and e_{ijkl} $(0,e^2)$ is the residual associated with the observation taken at the kth time in the jth bird of the ith species or subspecies. Fixed effects and variance components were estimated by the method of least squares (Searle 1971) and by Henderson's (1953) Method 3. Computer implementation was done with the general linear model (GLM) procedure of the Statistical Analysis System (SAS) (Goodnight 1979). This same procedure was also combined into their prospective species to create another analysis.

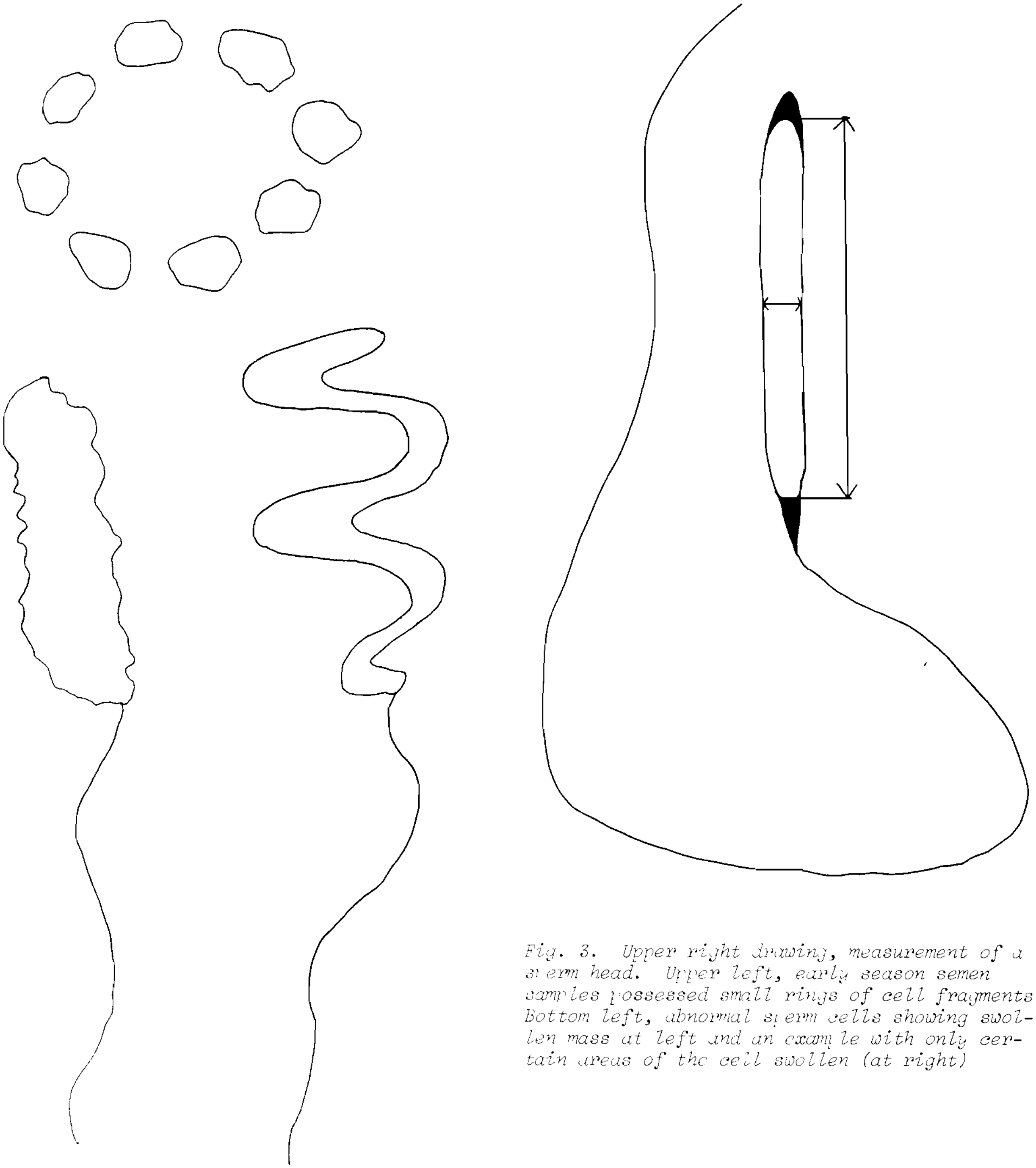

Fig. 3. Upper right drawing, measurement of a sperm head. Upper left, early season semen samples possessed small rings of cell fragments. Bottom left, abnormal sperm cells showing swollen mass at left and an example with only certain areas of the cell swollen (at right)

Due to the disproportionality of subclass numbers, an exact test of significance was not available to evaluate differences among species or subspecies. However, exact tests would be made to assess differences among time periods and species by time interactions. Significant ($\alpha = 0.05$) interaction was taken as evidence of differences among species and subspecies. Within these contrasts, single degree of freedom comparisons were made among species and subspecies (1st as species and subspecies, then with subspecies combined to analyze for species). The standard errors of these comparisons were calculated by multiplying the model mean square by the square root of appropriate linear functions of inverse elements of the coefficient matrix. The form of the estimable functions of the model involved in these comparisons is provided in Russman (1981).

RESULTS

Staining Technique

The procedures outlined in Materials and Methods for smearing, fixing, and staining were followed. However, when stained cells were viewed microscopically, they appeared abnormal in comparison to those in a live state. All samples were viewed live. There were 2 basic types of cells: 1 swollen in appearance similar in shape to that of a bratwurst sausage (as in the S type referred to by Gee and Temple 1978); the 2nd type was not quite as swollen but did not appear normal. Some of the swollen-type cells exhibited the "reverse" staining described by Wakely and Kosin (1951). This was supposed to be a study of seasonal changes in sperm head dimensions, but a proper microscope was not found until 1 month after data collection began. Consequently, this problem had to be solved quickly in order to obtain a valid survey of sperm head dimensions in the remaining month. A series of experiments were then undertaken to discover the cause of the swollen cells.

It appeared that the cells may have been swelling during the drying process. In order to fix the cells and maintain the correct morphology, a fixative had to be applied while the cells were still alive and fluid. A drop of semen was placed on the right end of the slide followed by an equal amount of Bouin's fluid. These were allowed to set for 5 minutes. The slides were then labelled and the solution allowed to flow down the glass and air dry. When viewed microscopically, those cells fixed with Bouin's appeared normal and very few, if any, swollen cells could be seen. This fixative also differentiated the acrosome and midpiece from the nucleus, making the former 2 a darker yellow in color. The slides were then taken through the staining procedure and cells were normal in appearance.

Sharlin's (1976) stain ratio of 4:1 aniline blue to eosin B was inadequate with the Bouin's fixing method. Several other ratios were then attempted; the Casarett ratio of 2:1, 1:4, and a 1:1 ratio of aniline blue to eosin B were tested. The final ratio of 1:1 proved to be optimum. On most cells stained with the 1:1 ratio the nucleus appeared green and the acrosome and midpiece pink, but some stained with the nucleus green and the acrosome and midpiece a darker green. This staining procedure allowed proper examination and photographing of cells for samples collected during the month of May.

Casarett (1953) reported a similar type of differentiation with variations of the eosin B-aniline blue stain. The acrosome, midpiece, tail, and nuclear membrane all stained varying shades of blue and the sperm head nucleus stained a light pink color. Casarett (1953) found the best results in fairly dilute samples. Thus, the stain reaction must depend on the sperm concentration in the sample; the concentration of sperm affects the proportion of stain that penetrates each cell.

Stain Reaction

The stain reaction to crane sperm varied from slide to slide just as it did in Sharlin's (1976) work with sandhill crane semen. Slides were only considered for measurement if they were well-stained and had easily distinguishable spermatozoa. Very heavily contaminated samples and samples containing high concentrations of sperm cells did not stain well so we concluded that sufficient dilution must occur before slide preparation. Again, it appears that the amount of penetration of the stain depends upon the concentration of cells on a slide, as was noted by Casarett (1953).

Sperm Morphology

The 6 basic types of sperm cells described by Gee and Temple (1978) were noted in this study. At the beginning of the breeding season, live semen samples examined in the field had small rings of what appeared to be cell fragments or immature, nondeveloped sperm cells (Fig. 3, upper left). These peculiar rings disappeared as the breeding season progressed. During the 1st part of the breeding season there was also a greater number of bent cells than were present later (Fig. 3, left bottom; Fig. 4, upper left). Later in the breeding season, the normal (N) type of sperm cell (Gee and Temple 1978) was the most predominant type collected during May (Fig. 4, center left, lower left, upper right). The sperm head itself was long and narrow with a well-stained acrosome

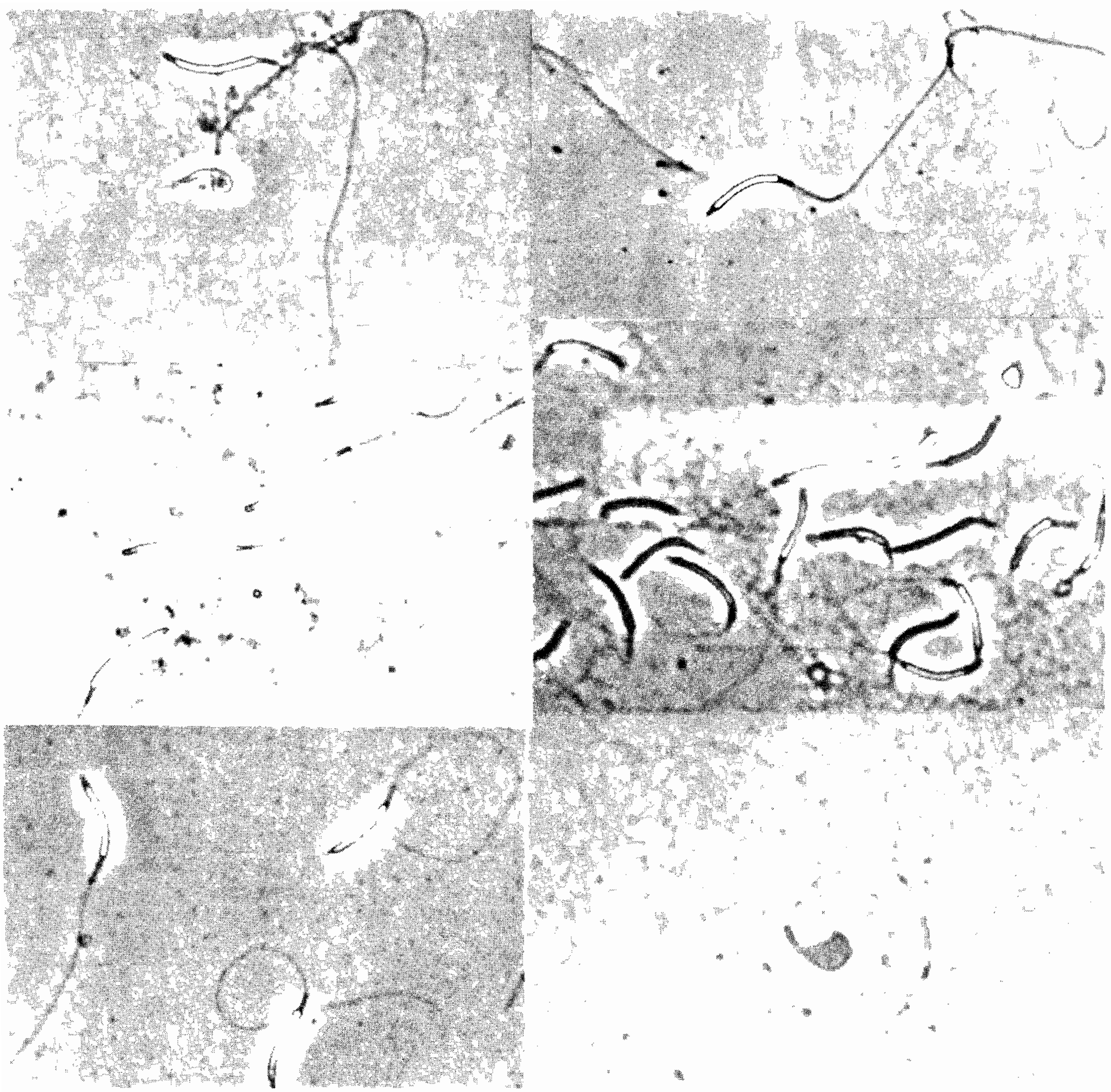

Fig. 4. Upper left, normal Siberian crane sperm just above 1 with a bent body. Center left, normal demoiselle crane sperm. Lower left, normal red-crowned crane sperm. Upper right, normal demoiselle crane sperm with tail entwined. Center right, giant sperm among other red-crowned crane sperm. Lower right, Florida sandhill crane sperm is partially engulfed by contaminants. Photos taken at 1600X. Sperm are magnified 3 million times.

and midpiece but the tail did not always stain. This phenomenon was most apparent in the more highly concentrated samples. In these concentrated samples there was also a greater number of bent sperm cells (B) as opposed to normal straight sperm cells.

There were several morphological abnormalities in all crane species studied that corresponded to those described by Gee and Temple (1978). Giant sperm (G) were observed in the samples 0-1% of the time. The average G sperm head length was 13 µm; however, width was the same as in normal sperm (Fig. 4, center right). Droplet (DL) cells or those sperm trapped or partially trapped in a spherical body were rare (1% of the time). Semen obtained by the massage technique usually contained some contamination. Although there is only gentle squeezing involved in obtaining semen, urates from the ureters, fecal matter from the rectum, blood from surface vessels, and lymph from erectile tissues can be released with the semen (Gee and Temple 1978). These contaminants are harmful to the sperm cells and can immobilize them within 15 minutes of collection (Gee and Temple 1978). Bird et al. (1976) discovered that contaminants in semen samples collected from kestrels covered 68% of the microscopic field. Temple (1972) found that by collecting hawk semen using the massage technique, as opposed to the cooperative technique, there was 6 times more contamination. These contaminants phagocytize the spermatozoa, filling them at a rapid rate, causing more bent cells, causing more engulfed or droplet cells, and creating a less than desirable staining reaction (Fig. 4, lower right; Fig. 5, left-hand photos).

There were very few swollen cells present on the slides after the change in cell fixation technique. The few swollen cells that were present were attributed to the effect of contaminants on the cells. The contaminants caused rapid death; therefore, cell death occurred before proper fixation. Another result of contamination was deformed cells, those swollen in certain areas of the cell body (Fig. 3, bottom left).

Abnormalities of the separate sperm entities included: acrosome abnormalities consisting of enlarged acrosomes that resembled a ball or bulbous mass at the end of the cell (Fig. 5, lower left). Some acrosomes were also elongated. On 1 extreme they had a small protrusion of the nucleus, while on the other extreme they had long structures protruding from the nucleus. The nucleus (sperm-head itself) did not vary a great deal except for the occasional swollen-type or bent heads. In some samples there appeared to be a great amount of variation in size ranging from abnormally small heads to abnormally large sperm heads (Fig. 5, upper right). Most tails appeared normal and were 2 to 3 times the length of the sperm head. Some sperm possessed crooked tails or 2 tails and many were intertwined with each other or broken off (Fig. 5, center right). "Bratwurst" sperm cells are pictured in Fig. 5, lower right.

Sperm Head Dimensions

Means and standard errors of sperm head dimensions were calculated for the subspecies and species of cranes studied (Table 1). Sperm head lengths ranged from 6.5 ± 0.18 µm for the Indian sarus crane to 8.1 ± 0.97 µm and 8.1 ± 0.10 µm for the Florida sandhill and demoiselle, respectively. Bird size does seem to have an inverse relationship with sperm head length. The largest crane, the Indian sarus, had the smallest sperm, while the smallest existing species, the demoiselle crane, had the largest sperm head length (these are only rough estimates inferred from raw means).

The sperm head width ranges from 0.8 ± 0.010 µm and 0.8 ± 0.012 µm in the common crane and demoiselle, respectively, to 1.0 ± 0.019 µm in the whooping crane. The approximate sperm head area ranges from 6.0 ± 0.18 µm in the Indian sarus to 7.1 ± 0.13 µm in the brolga (Table 1).

The true sperm head areas, calculated using Equation 1, ranged from 4.9 m in the Indian sarus to 7.3 ± 0.14 µm in the white-naped crane (Table 2). Although we must consider the small sample numbers, the Indian sarus appears to have the smallest sperm. Estimates of variance components are given in Russman 1981. A species and subspecies by time interaction was significant ($P < 0.0001$) (Table 3).

Many of the species had only 1 or 2 birds or a minimal number of sperm per species; consequently, selective contrasts were made. All species and subspecies were compared to the red-crowned cranes because that species contained the largest sample of individual birds (7). The model used was previously defined (Russman 1981). All species and subspecies were contrasted to the red-crowned crane. From these contrasts inferences could be made concerning all species tested. The whooping crane did not warrant analysis because it contained only 1 sample (10 sperm from a frozen semen sample) from 1 male bird.

Comparisons of subspecies and species showed that sperm head length of the red-crowned crane was significantly different from all others except the greater sandhill, Stanley, and Siberian cranes. The Stanley crane was represented by only 1 individual and few samples were available from Siberian cranes. Head width results revealed differences only with greater sandhill, eastern sarus, and Indian sarus. Thus, there is much less variability in sperm head width than in head length. Comparisons of approximate sperm head area showed significant differences with all species except eastern sarus, Indian sarus, Stanley, and Siberian cranes.

The "approximate" sperm head area gives a better factor with which to measure differences than just using sperm head length or width (see Russman 1981 for specific estimate values).

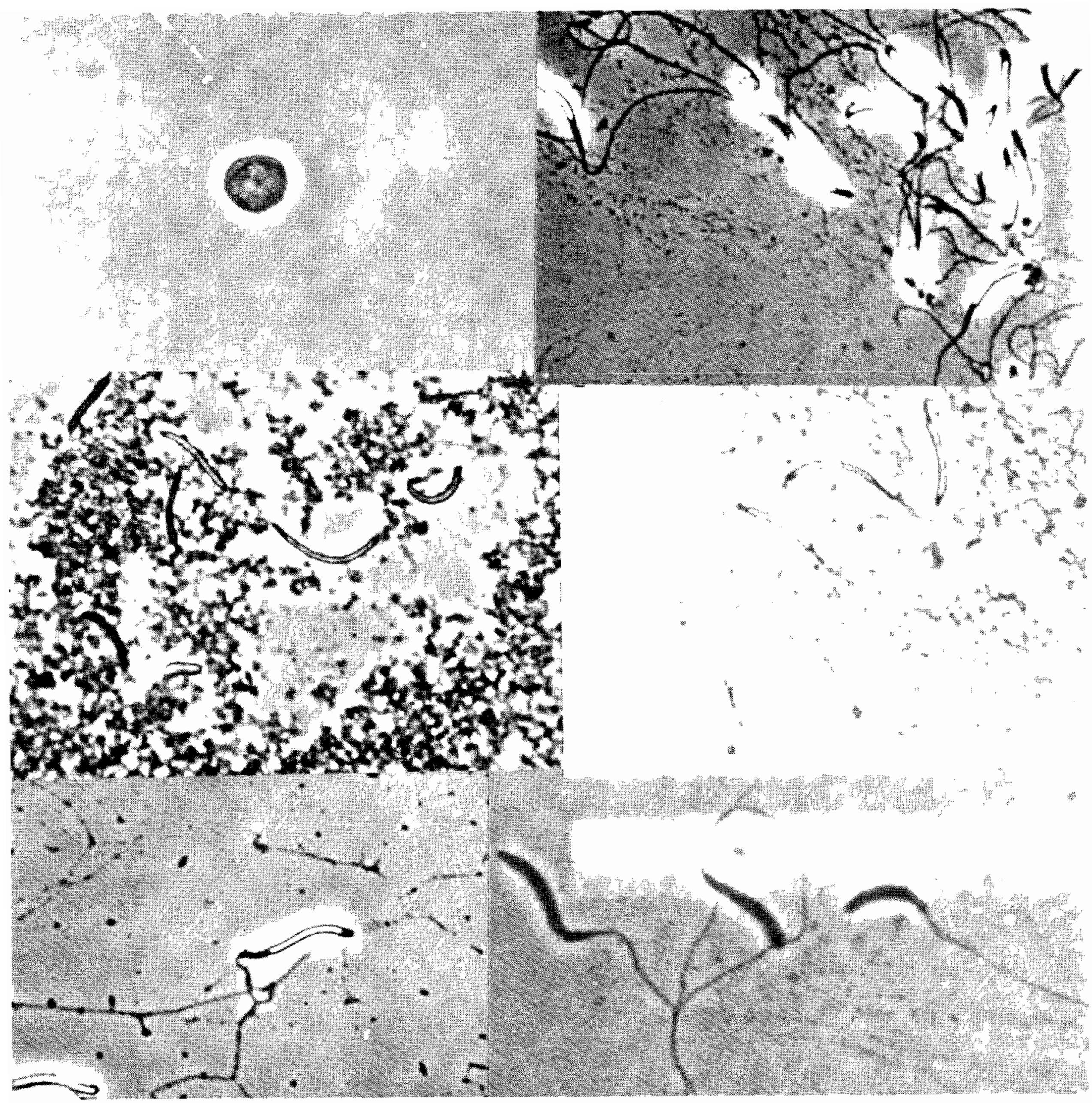

Fig. 5. Upper left, red-crowned crane sperm cell engulfed by contaminants. Center left, Stanley crane sperm among contaminants. Lower left, greater sandhill crane sperm possessing elongated acrosome and entwined tail. Upper right, size variability in greater sandhill crane sperm from 1 bird. Center right, white-naped sperm in top right corner has a bent tail. Lower right, swollen, reverse staining cells as a result of improper fixation. Sperm magnified 3 million times. Photos taken at 1600X.

When subspecies were combined and contrasted as species, a species by time interaction was significant ($P < 0.0001$)(Table 3). Sperm head length was then significantly different between red-crowned and all species except Stanley and Siberian cranes. Sperm head width contrasts revealed less significance than head length estimates. Only the sarus species was different from the red-crowned crane. A comparison of approximate sperm head area indicated all species except the sarus, Stanley, and Siberian cranes were different from the red-crowned crane.

Table 1. Mean head length, head width, and approximate head area of crane sperm.

Crane species or subspecies	Sperm measured	Head length[a] (μm)	C.V.[b]	Head width (μm)	C.V.	Approximate sperm head area (μm^2)	C.V.
Red crowned	440	7.5 ± 0.052	14.0	0.9 ± 0.007	15.5	6.5 ± 0.064	19.9
White-naped	330	7.7 ± 0.053	12.2	0.9 ± 0.008	15.5	6.6 ± 0.070	18.9
Whooping	10	6.9 ± 0.090	14.5	1.0 ± 0.019	19.1	6.9 ± 0.140	20.8
Common	150	7.8 ± 0.082	14.1	0.8 ± 0.010	16.3	6.5 ± 0.100	21.2
Sandhill	380	7.7 ± 0.060	15.1	0.9 ± 0.007	15.3	6.7 ± 0.073	21.2
Lesser sandhill	80	7.5 ± 0.110	12.5	0.9 ± 0.014	14.2	6.6 ± 0.150	20.4
Greater sandhill	140	7.4 ± 0.090	14.4	0.9 ± 0.012	15.5	6.5 ± 0.110	19.4
Florida sandhill	160	8.1 ± 0.970	15.1	0.9 ± 0.010	15.5	7.0 ± 0.120	22.4
Sarus	150	7.1 ± 0.100	18.0	0.9 ± 0.120	16.1	6.7 ± 0.140	26.4
Indian sarus	60	7.2 ± 0.120	18.2	0.9 ± 0.015	17.0	6.9 ± 0.170	27.3
Eastern sarus	90	6.5 ± 0.180	14.9	0.9 ± 0.021	12.4	6.0 ± 0.180	16.4
Demoiselle	100	8.1 ± 0.100	12.6	0.8 ± 0.012	14.5	6.8 ± 0.140	20.0
Stanley	80	7.2 ± 0.120	15.1	0.9 ± 0.140	14.2	6.4 ± 0.140	19.4
Brolga	100	8.0 ± 0.120	15.4	0.9 ± 0.130	14.7	7.1 ± 0.130	18.4
Siberian	30	7.7 ± 0.180	13.2	0.9 ± 0.190	12.2	6.6 ± 0.230	19.0
Wattled	50	7.8 ± 0.150	13.2	0.9 ± 0.220	17.1	7.0 ± 0.190	20.0

[a] Mean ± standard error of the mean.

[b] C.V. is the coefficient of variation.

Table 2. Species means of areas calculated from photographs by the digitizer.[a]

Species	Number of sperm measured	Area mean[b] in μm^2	C.V.
Red-crowned	2	6.6 ± 0.13	2.8
White-naped	36	7.3 ± 0.14	11.9
Whooping	c	--	--
Common	9	5.9 ± 0.23	11.4
Sandhill	24	6.6 ± 0.18	13.1
Lesser sandhill	1	7.1 --	--
Greater sandhill	10	6.1 ± 0.13	6.9
Florida sandhill	13	7.0 ± 0.13	13.4
Sarus	5	5.9 ± 0.30	11.4
Indian sarus	4	6.1 ± 0.23	7.7
Eastern sarus	1	4.9 --	--
Demoiselle	26	6.5 ± 0.12	9.6
Stanley	2	6.2 ± 0.40	9.1
Brolga	11	7.0 ± 0.70	33.1
Siberian	10	6.6 ± 0.28	13.2
Wattled	36	6.6 ± 0.18	16.7

[a] Means were calculated using Equation 1.

[b] Mean ± standard error of the mean.

[c] Frozen sample from 1 bird deemed not worthy of analysis.

Table 3. ANOVA table for all species and subspecies differences for sperm head length, head width, and approximate head area.

Variable	Source	DF	SAS type IV SS	F value	PR < F
Species and subspecies differences					
Head length	SP	12	164.71128178	14.10	0.0001
	BRD(SP)	14	95.38157734	7.00	0.0001
	T	16	63.15322264	4.05	0.0001
	SPxT	88	223.64195932	2.61	0.0001
Head width	SP	12	0.74234332	4.43	0.0001
	BRD(SP)	14	1.78982928	9.15	0.0001
	T	16	2.06824602	9.25	0.0001
	SPxT	88	5.55364585	4.52	0.0001
Approximate head area	SP	12	62.23539943	3.62	0.0001
	BRD(SP)	14	128.93508727	6.42	0.0001
	T	16	251.04821441	10.95	0.0001
	SPxT	88	540.94169970	4.29	0.0001
Species head length	SP	9	136.34632945	15.40	0.0001
	BRD(SP)	17	141.87331635	8.48	0.0001
	T	16	88.03684851	5.59	0.0001
	SPxT	74	193.02117652	2.65	0.0001
Head width	SP	9	0.59947122	4.68	0.0001
	BRD(SP)	17	1.89304792	7.83	0.0001
	T	16	1.93214718	8.49	0.0001
	SPxT	74	4.94031950	4.70	0.0001
Approximate head area	SP	9	48.41332606	3.69	0.0002
	BRD(SP)	17	125.21526983	5.05	0.0001
	T	16	265.70828686	11.39	0.0001
	SPxT	74	480.65779787	4.46	0.0001

The same analysis was followed for the true sperm head area calculated using the digitizer. The sample number was quite small, sometimes 1 sperm was digitized per species. True area was different ($P < 0.0001$) between species (Table 4). All species except eastern sarus, Siberian, and wattled cranes were significantly different from the red-crowned crane. These results may be because of small sample size. True sperm head area again showed significant differences ($P < 0.0001$) when all subspecies were combined into their own species (Table 4). Individual comparisons revealed that all species except common, sandhill, Siberian, sarus, and wattled cranes were different ($P < 0.0001$) from the red-crowned crane. Thus, 8 out of 14 species were different from the comparison species (red-crowned cranes)(Table 5).

These data demonstrated that there were differences in sperm morphology among species of cranes, especially in sperm head length. More contrasts (comparisons) might have exhibited significance if larger sample numbers had been available. This study will hopefully provide a good foundation for further studies in crane sperm morphology. From this base-line data, we can develop superior methods of evaluating fertility, and design techniques for cryogenic preservation of crane semen. These advances will in turn improve captive management and aid in the successful propagation of these endangered species.

Table 4. ANOVA table for all subspecies and species differences for true sperm head area as calculated by the digitizer.

Variable	Source	DF	SAS type IV SS	F value	PR < F
Species and subspecies	SP	11	23.64449315	4.16	0.0001
	BRD(SP)	3	0.02164628	0.01	0.9941
	T	10	25.99847834	5.03	0.0001
	SPxT	1	0.59978596	1.16	0.2834
Species only	SP	9	20.54401109	4.42	0.0001
	BRD(SP)	4	1.29061336	0.62	0.6460
	T	10	25.99847834	5.03	0.0001
	SPxT	1	0.59978596	1.16	0.2834

Table 5. Results of species comparisons using red-crowned cranes as the comparison species.

Variable	Significant	Nonsignificant	Variable	Significant	Nonsignificant
Head length	White-naped Wattled Common Sandhill Sarus Demoiselle Brolga	Stanley Siberian	Head area Approximate	White-naped Wattled Common Sandhill Brolga Demoiselle	Sarus Stanley Siberian
Head width	Sarus	White-naped Wattled Common Sandhill Demoiselle Brolga Stanley Siberian	True	White-naped Common Sandhill Brolga Demoiselle Stanley	Sarus Siberian Wattled

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NATURAL AND ARTIFICIAL INCUBATION OF CRANE EGGS: IMPLICATIONS FOR CAPTIVE PROPAGATION

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Abstract: Temperatures of crane eggs under natural incubation were monitored using thermocouple wires inserted into the air cells. Similar data were recorded from eggs in a forced-air incubator at the International Crane Foundation. One egg with a developing embryo and infertile eggs were monitored. The mean cloacal temperature of common crane (*Grus grus*) was 40.0°C. Brood patches in incubating males and females, and nonbreeding cranes were examined and their dimensions and temperatures recorded. The mean incubation temperature of a fertile common crane egg was 37.9°C and that of an infertile common crane egg was 36.3°C. Temperature gradients throughout the eggs varied from 0.32 to 0.43°C for eggs incubated artificially and 7.4°C for eggs under natural incubation. Temperatures recorded during natural incubation showed variances from 1.98 to 3.31°C and during artificial incubation from 0.08 to 0.27°C. The importance of temperature variance in embryonic development is discussed.

As crane species become increasingly threatened, it becomes more crucial to develop the best techniques possible for captive propagation. The egg production of cranes can be increased several-fold by removing the eggs from the nest and allowing the cranes to replace the clutch. The eggs can then be incubated artificially and the young reared in captivity. Several centers (e.g., International Crane Foundation, New York Zoological Society, Vogelpark Walsrode, and Smithsonian Institution's National Zoo Conservation Research Center) have developed major crane breeding programs. Several of these centers have experienced difficulties hatching certain species of crane. This problem has led me to study the natural incubation temperature of several species and to attempt to determine how this information can be used to improve artificial incubation. This paper describes the results of my research to date.

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MATERIALS AND METHODS

Captive cranes were studied at the International Crane Foundation, Baraboo, Wisconsin. Data were recorded from May through July 1980 and May through June 1981. Egg temperatures were monitored with copper-constantan thermocouples. Thirty-six-gauge wires were epoxied to the eggs and run from the eggs down into the nest litter. From the nest litter, 20-gauge wires led approximately 15 m to the recording device. Internal egg temperatures were monitored with the thermocouple junction inserted 0.25 cm into the air cell of the egg. This wire was inserted through a hole drilled into the air cell with a 0.16-cm drill bit which had been previously sterilized in 70% alcohol. Brood patch temperatures and gradients through the eggs were monitored with wires attached to the outside of the eggs. Eggs were dipped in a warmed germicide solution after removal from the nest and all wires were sterilized in 70% alcohol for 20 minutes before attachment.

In 1980 temperatures were recorded manually in a blind using a West Pyrotest Galvanometer, Model 9B, accurate to ±0.5°C. The temperatures were read every 15 minutes during observation periods and entered into a field notebook. Cloacal and inner thigh temperatures and brood patch temperatures of nonbreeding male cranes were measured on a Yellow Springs Instrument Company telethermometer with a latex-coated temperature probe. In 1981, temperatures in the nest and in the artificial incubator were recorded automatically every 30 minutes with a Campbell Scientific Data Logger, Model CR5, accurate to ±0.1°C. Each temperature monitoring device was checked in an ice bath and was accurate to ±0.5°C. The artificial incubator was a forced-air cabinet type set at 37.5°C. Student's t-tests were used to compare temperature means. An F-test was used to compare variances. Significance was set at the 0.05 level.

RESULTS

Both breeding and nonbreeding common cranes had defeathered patches on their breasts during the normal breeding season (Table 1). The mean defeathered area of the breeding cranes was significantly larger than the defeathered area of the nonbreeders ($P < 0.06$, $T = 2.859$). These areas were calculated by multiplying the maximum length by the maximum width and dividing by 2, assuming a

Table 1. Calculated (maximum length X maximum width/2) brood patch areas (cm^2) of breeding and nonbreeding common cranes.

Category and sex	Brood patch area Right	Brood patch area Left
Breeding ($\bar{X}$ = 29.5)		
Male 1	19	24
Male 2	39	33
Female 2	42	20
Nonbreeding ($\bar{X}$ = 15.4)		
Male 1	19	20
Male 2	12	NA
Male 3	18	8

roughly diamond-shaped area. Every other crane species subsequently examined at ICF showed a similar defeathered area. A later examination on 28 June 1980, after the normal breeding season of the common cranes at ICF, showed that the brood patches were in the process of refeathering.

Mean brood patch temperatures (Table 2) of breeding birds were not significantly different from brood patch temperatures of nonbreeders ($P > 0.05$). Mean brood patch temperatures also were not significantly different from mean cloacal or mean inner thigh temperatures ($P > 0.05$).

Table 3 shows internal egg temperatures recorded during natural incubation and in an artificial incubator. Data for the common crane egg with the live embryo were recorded during the last 4 days of incubation. Only those

Table 2. Cloacal, brood patch, and inner thigh temperatures of common and white-naped cranes in captivity.

Body area and reproductive status	Species	Individuals	Measurements	$\bar{X}$ (°C)	SD (°C)
Cloaca	Common	7	7	40.0	0.76
Brood patch					
Breeding	Common	2	58	39.3	0.77
Breeding	White-naped	2	10	39.5	0.98
Nonbreeding	Common	3	18	40.2	0.71
Inner thigh					
Nonbreeding	Common	3	3	39.8	0.56

Table 3. Internal temperature of crane eggs under natural and artificial incubation.

Type of incubation and egg status	Species	Eggs	Measurements	$\bar{X}$ (°C)	SD (°C)
Natural incubation					
With live embryo	Common	1	116	37.9	1.41
Infertile	Common[a]	1	97	36.3	1.58
With dead embryo	Sandhill[a]	1	14	36.5	1.82
Infertile	White-naped	1	71	36.5	1.64
Artificial incubation					
Infertile	Common	1	36	37.7	0.52
Infertile	Common[b]	1	54	37.2	0.09

[a] These eggs were monitored simultaneously while being incubated by a common crane.

[b] The incubator door was not opened while this temperature was being recorded.

Table 4. Temperature gradients through crane eggs being artificially and naturally incubated.

Type of incubation and egg status	Species	Eggs	Measurements	$\bar{X}$ (°C)	SD (°C)
Natural incubation					
With live embryo	Common	1	50	7.4	1.76
Artificial incubation					
Infertile	Common	1	37	0.43	0.12
Infertile	Common[a]	1	55	0.32	0.08

[a] The incubator door was not opened while this temperature was being recorded.

recordings taken when the parent was sitting tightly on the nest were used in computing the temperature mean. The infertile common crane egg and the sandhill crane (*Grus canadensis*) egg with the dead embryo were incubated simultaneously by a common crane. Mean temperatures of these 2 eggs were not significantly different ($P > 0.05$) nor were the variances about the means ($P > 0.05$). The mean incubation temperature of an infertile egg incubated by a white-naped crane (*Grus vipio*) was similar to that of the infertile common crane egg and the dead sandhill egg ($P > 0.05$). The variances of the means were also not significantly different.

The mean incubation temperature of the common crane egg with the live embryo, however, was significantly higher ($P > 0.05$) than either the infertile common egg or the infertile white-naped crane egg.

The infertile common crane egg 1st listed under artificial incubation in Table 3 was kept in an incubator that had the door opened periodically during the observation period. The 2nd infertile common crane egg listed was monitored in the same incubator but the door was not opened while the temperature was being recorded. The variance about the mean during this latter period was significantly less than the variance when the incubator door was frequently opened ($P < 0.001$, $F = 9.339$). The mean ambient temperatures inside the incubator during these 2 periods, as measured in the vicinity of the eggs being monitored, were identical.

The mean incubation temperatures of both artificially incubated eggs were significantly higher than the infertile eggs under natural incubation ($P < 0.05$). The variances about the mean of the naturally incubated eggs were significanlty greater than the artificially incubated eggs ($P < 0.05$).

Table 4 shows the differences in mean temperature gradients throughout eggs under natural and artificial incubation. The mean gradient existing in natural incubation was 7.4°C. The mean gradient of eggs under artificial incubation varied from 0.32°C in the incubator that was not opened while the temperature was being recorded to 0.43°C in the incubator that was opened periodically during the recording period.

DISCUSSION

Natural Incubation

The process of heat transfer during artificial incubation of eggs is a much different process than that in natural incubation. In natural incubation, heat is generally conducted to the egg from the body of the incubating parent through a defeathered, highly vascularized area--the brood patch. The heat transfer relationship between the parent and its eggs can be thought of as though the eggs are an extension of the bird's body core (Drent 1975). The morphological properties of the brood patch do not raise its temperature, but allow a rapid transfer of heat to the brood patch area.

The rate of heat transfer is dependent on the temperature gradient from brood patch to eggs and the area of contact. For heat to be transferred to the eggs, the eggs must be cooler than the brood patch. Therefore, eggs will cool the brood patch when the parent is sitting on the nest. This phenomenon is illustrated in Table 2 which shows the brood patch temperatures of common and white-naped cranes, measured when the birds were sitting on their eggs, to be slightly lower than the brood patch temperatures of nonbreeding common cranes.

Nonbreeders did develop brood patches. Bailey (1952) discovered that in passerine birds the seasonal formation of the brood patch was under hormonal control. Lloyd (1965) suggested that behavioral cues stimulate the release of hormones responsible for brood patch formation in the European starling (*Sturnus vulgaris*). It appears, however, that behavioral responses to courtship stimulation are not necessary for brood patch development in cranes. Table 2 also shows that the thigh temperature of nonbreeders is similar to temperatures of their brood patches.

Artificial Incubation

The process of artificial incubation transfers heat by convection. This is a complex process and the rate of heat transfer is dependent on several variables--egg geometry, surface area, speed of air flow in the incubator, and orientation of the egg to air flow. Thus, different incubators vary widely in the range of temperature variation and homogeneity of temperature through the incubator. Incubators are of 2 types--still air incubators in which eggs are warmed by radiating heat from above, and forced air incubators which maintain a more homogeneous temperature by circulating warmed air to most parts of the incubator.

The crane breeder is interested in the optimal temperature for development. When investigating this problem, it is essential to know how and where the temperature has been monitored. Internal egg temperatures, the upper, lateral, and lower surfaces of the egg, and the nest air temperature can be measured. Internal egg temperature can be monitored in the air cell, the center of the egg mass, or adjacent to the embryo. If an artificial egg has been used, that represents a different set of considerations. The conductivity of an artificial egg may vary greatly from that of a natural egg. Also, the artificial egg used in telemetry, although convenient, cannot indicate the contribution of embryonic metabolism to the egg's temperature.

Table 3 shows internal egg temperatures measured under natural and artificial incubation. The infertile common crane egg and the sandhill egg with the dead embryo were incubated simultaneously by a common crane. The sandhill crane egg was approximately 20% larger than the common crane egg, but their mean temperatures and their variances about the mean were not significantly different. This suggests that the incubating adult can compensate for a larger than normal egg, a factor of interest to those researchers involved in cross fostering experiments.

Embryonic Heat Production

The difference in incubation temperature between an infertile crane egg and 1 with a live embryo was approximately 1.5 C. This difference was a direct result of embryonic heat production. Drent (1970) found that embryonic heat production in the herring gull (*Larus argentatus*) surpassed the evaporative heat loss of the egg after 10 days of incubation. A similar influence of embryonic heat production was reported for the domestic chicken and the domestic duck (Drent 1975). Figure 1 illustrates the relative energetic contribution of embryo and parent herring gull to the incubation process. The embryo provides 75% of the total heat energy on the last day of incubation. Ricklefs (1974) calculates a similar contribution from the house wren (*Troglodytes aedon*) based on data from Kendeigh (1940).

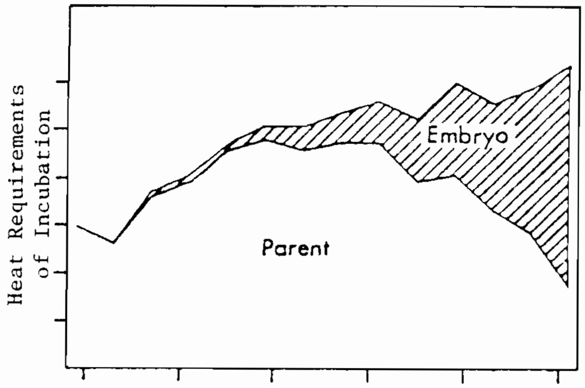

Fig. 1. The relative contributions of the embryo and the parent to the heat requirements of incubation in the herring gull egg (from Ricklefs 1974).

In artificial incubation the incubator replaces the energetic contribution of the parent. Therefore it seems apparent that the temperature in the incubator should be reduced toward the end of the incubation period. Rolnik (1968) cites numerous references supporting this view. This is especially important if all the eggs are at the same stage of development because the combined heat output of the embryos can considerably raise the temperature in the incubator.

Temperature in the Incubator

If the crane breeder's purpose is to keep the incubator at the mean temperature present during natural incubation, then the proper action is to maintain the incubator, during the 1st half of incubation, at the mean natural incubation temperature of an infertile egg. In the latter half of incubation the embryos will increasingly generate heat and the incubator temperature should be adjusted so egg temperatures do not exceed the mean temperature recorded from an egg with a live embryo generating metabolic heat. It is worthwhile to note here that, depending on incubator conditions, the temperature measured on the door or ceiling of the incubator may not accurately reflect the temperatures of the eggs. Temperatures should be measured from the eggs themselves.

Temperature Variance

The variation in temperature is undoubtedly as important as the mean temperature. Table 3 shows a wide disparity, in variance about the mean, between those eggs maintained in an artificial incubator and those incubated naturally. Rolnik (1968) cited several investigators who found a marked increase in artificial hatching success when there were greater variations about the mean temperature. However, he stated that the more domesticated a species is, the less the embryos of that species require temperature fluctuations for hatching success. Rolnik (1968:292) further stated that "frequent fluctuations of temperature are a characteristic feature of the natural development of bird embryos. The developing embryos readily adapt to fluctuations of the nest temperature, and as a result of the long process of natural selection these fluctuations have inevitably become indispensable for normal development."

It is a well-known fact that the metabolic rate in animals increases exponentially with increasing temperature. The term Q_{10} refers to the increase in metabolic rate caused by a 10°C increase in temperature. The recorded Q_{10} values for the heart rate of avian embryos in the temperature range of normal incubation were between 1.4 and 1.9 (Bennett and Dawson 1979). Because the function is exponential, an increase in temperature will cause a larger change in the metabolic rate than an equal decrease in temperature. Therefore a wider variance about a mean incubation temperature will cause a greater net increase in metabolic rate than will a narrow variance about the same mean. This could be a partial explanation for the advantage of larger temperature variances in incubating wild bird eggs.

Allowing the temperature of eggs to fluctuate about a mean would then seem desirable. Frequently opening the door and allowing the thermostat in the incubator to cycle above and below its set point would produce an adequate variance about the mean. Prolonged cooling of the eggs may have a beneficial effect (Rolnik 1968), but this will also lower the mean temperature of the eggs.

Temperature Gradients

Table 4 shows the large difference in temperature gradients through eggs under natural and artificial incubation. However, this gradient is probably important only in terms of its effect on the embryo, which in the early stages of development floats on top of the egg mass where the temperature is the highest. As the embryo mass becomes larger, the gradient may play a more important role.

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DOMINANCE AND SOCIAL BEHAVIOR IN A MIXED SPECIES FLOCK OF CRANES

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Abstract: From 17 April to 6 July 1979 the behavior of a mixed species flock of cranes was studied at the International Crane Foundation, Baraboo, Wisconsin. The flock, composed of 16 individuals and 7 species, formed a well-defined dominance hierarchy: linear intraspecifically, and both linear and triangular interspecifically. Triangularity, a sign of instability, was primarily caused by the presence of the common cranes (*Grus grus*), late arrivals to the flock structure. The alpha bird was a male brolga (*G. rubicunda*) who won all encounters with other flock members. Size, age, and sex were not consistent factors in interspecific dominance. Females were dominant to at least 2 males interspecifically, and the smallest bird in the flock, a hooded crane (*G. monacha*), was dominant to several birds much larger than himself. More aggression was noted interspecifically than intraspecifically. Hand-reared birds of the same species tended to flock together with the exception of the white-naped cranes (*G. vipio*). Frequency of stretch-neck-burr, an agonistic-reproductive behavior common to most flock members, was related to dominance intraspecifically, and was essentially absent in the sarus (*G. antigone*), subordinate brolga, and white-naped cranes. The dominant male brolga and the 2nd ranking sarus female were frequent companions; this and other evidence indicates the possibility of their pairing in the future.

This paper concerns research conducted at the International Crane Foundation (ICF) on a captive flock of cranes which contained 16 birds of 7 different species (Table 1). The social structure of the flock was studied regarding dominance and dominance-related behaviors. Sub-groupings within the flock (i.e., preferential associations between birds) were also quantified. The heterogeneity of the flock allowed a comparison between intraspecific and interspecific dominance, and the testing of several hypotheses: e.g., are size, sex, or hatch history (hand-reared or wild-caught) an influence on dominance? And finally, since the majority of the birds were hand-reared, I hoped to discover whether intraspecific subgroupings would occur despite the lack of a parental model.

Table 1. Spring-summer flock composition, International Crane Foundation, 1979.

Species	Males:females
Sarus	2:2
Brolga	2:0
Red-crowned	2:1
Common	3:0
Sandhill	1:0
White-naped	1:1
Hooded	1:0

Although a flock of this diversity would never occur in the wild, interspecific groups of cranes do occur in Korea (red-crowned [*G. japonensis*] and white-naped cranes), India (sarus and Siberian [*G. leucogeranus*] cranes), Australia (sarus and brolga cranes), and in the United States (sandhill [*G. canadensis*] and whooping cranes [*G. americana*]). This and further research should help to illuminate some of the problems of sympatry among cranes.

I wish to thank George Archibald and ICF for making this study possible. Special thanks to Vickie LaRue and Steve Latta for their help in gathering data. This paper is dedicated to the memory of Calvin, the sandhill crane.

METHODS

Flock observations were begun on 17 April 1979 and continued through 6 July 1979. All members of the flock had been together for at least 1 year before this study. Formerly ranging over a 4-ha area, in March of 1979 they were confined to a smaller outside pen and barn due to the implementation of quarantine procedures. This limitation of movement created an ideal situation for a study, because the entire flock was easily observed.

The study area (Fig. 1) was approximately 30 x 22 m (0.066 ha), and consisted of a barn open at 2 ends, and a yard composed of both sand and grass substrates. Four food sources were constantly available, 2 within the barn, and 2 in the yard. Four water sources, a free-flowing trough and 3 large buckets, were also available in the yard. Observations were made from a woods outside the eastern perimeter of the enclosure, initially in plain view of the birds, and later from a blind at the same location. All observations were at least 1 hour in duration, and took place at variable times of day.

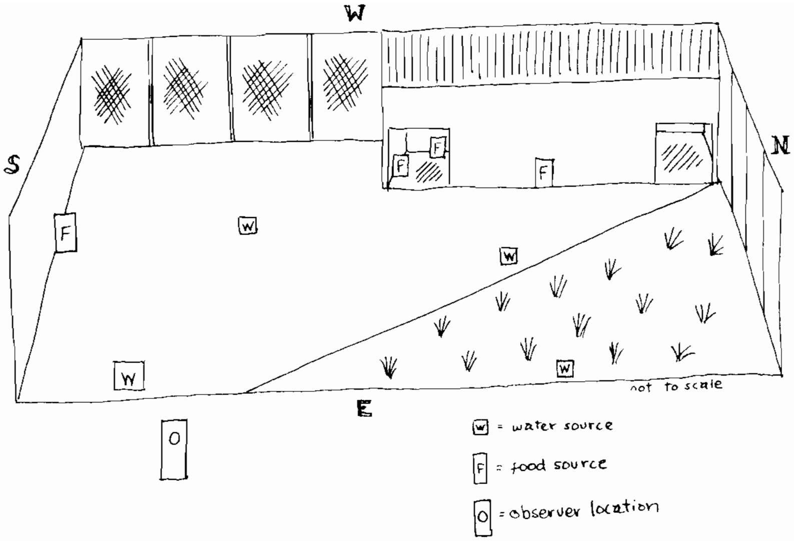

Fig. 1. The 30- x 21-m study area with the eastern fence removed for clarity.

Individuals were designated by the use of color bands above the tibiotarsal joint of the right or left leg. Birds were not color-banded if they were the sole representative of a species, or if they were the last unbanded member of a species and to band them would create undue stress. Birds were sexed via the sexually diethic unison call (Archibald 1975). All hand-reared birds were hatched at the ICF.

Dominance interactions were recorded in 2 categories: high intensity (pecks, threats, or chases), and low intensity (simple displacement). Observation of bird behavior before recording interactions was important for several reasons. Localized locomotion of cranes generally signalled an impending interaction and allowed the focus of attention to shift to that area; otherwise, a general visual scan was used. Occasional "free-for-alls" erupted, and interactions were then recorded as rapidly and as accurately as possible. Outcomes were not recorded if there was any doubt about what had occurred. Prior observation of behavior was also important in the recording of displacements, to prevent recording a simple succession (i.e., 1 bird finishes eating and another moves in) as a dominance displacement.

Certain other crane behaviors, described in the discussion section, were recorded to see if they could be correlated with dominance. These were dancing, nesting, stretch-neck-burr (SNB), and unison calling (UC). The social or flocking preferences (subgroupings) of the cranes were determined by recording all instances of peaceable, close proximity between 2 or more birds.

RESULTS

Dominance Hierarchy

Table 2 lists the identification of and the background data on all individual cranes. Individual dominance or rank was measured by the number of winning encounters against other flock members. Tables 3 and 4 show the outcomes of high and low intensity dominance interactions. Outcomes were consistent at both levels of a bird's rank. There were fewer high-intensity interactions (324) than low-intensity interactions (548). Cranes in the middle of the hierarchy were more likely to have aggressive encounters than were birds at either end, i.e., H(71) and WW(91) vs. GB(28) and GC(29). A linear dominance hierarchy was the rule within species. The entire flock formed a linear hierarchy which showed some aspects of triangularity, evidenced in the dominance tables by those outcomes greater than 1 listed above the diagonal. Triangularity within the hierarchy was created primarily by the presence of the 3 common cranes, BC, NC, and GC, and partly by NB, a male brolga.

Table 2. Background data and identification of individuals within the mixed species flock of cranes.

Species	Color band	Abbreviation	Sex	Age	Hatch history
Sarus	White	WS	M	2	Hand-reared
Sarus	Red	RS	M	2	Hand-reared
Sarus	Green	GS	F	2	Hand-reared
Sarus	Black	BS	F	2	Hand-reared
Brolga	Green	GB	M	8	Wild-caught
Brolga	None	NB	M	adult[a]	Wild-caught
Sandhill	None	S	M	4	Hand-reared
Hooded	None	H	M	2	Hand-reared
Red-crowned	Red	RJ	M	2	Hand-reared
Red-crowned	White	WJ	M	2	Hand-reared
Red-crowned	Black	BJ	F	2	Hand-reared
White-naped	White	WW	M	2	Hand-reared
White-naped	None	NW	F	3	Hand-reared
Common	Black	BC	M	adult	Wild-caught
Common	Green	GC	M	adult	Wild-caught
Common	None	NC	M	adult	Wild-caught

[a] Exact age of all adults unknown; they were acquired as adults.

Figure 2 shows a model of the flock dominance hierarchy that for simplicity excludes the common cranes. A male brolga (GB) was the undisputed alpha bird. RS and WS, both male sarus, were the 2nd and 3rd ranking birds. The only element of confusion is caused by male brolga NB, who is subordinate to the 3 top-ranking males and sandhill crane S, but dominant to the 2 female sarus (GS and BS) and all birds ranked below S. The hierarchy then proceedes in a linear fashion with the sarus females dominant to S, S dominant to H, and so on, down through BJ, a female red-crowned crane.

BJ would appear to be at the bottom of the hierarchy. However, the addition of the common cranes to the dominance model changes her subordinate status, because all of the red-crowned cranes were dominant to all of the common cranes. The social relationships of the common cranes were quite convoluted and are modeled separately (Fig. 3). Once again, the hierarchy was linear intraspecifically. The highest ranking common crane, BC, was dominant to all the birds shown (NC, GC, H, WW, and NW). NC, the 2nd ranking common crane, was codominant with H, subordinate to BC and WW, and dominant to NW and GC. And, finally, GC was dominant to H and NW, and subordinate to all the rest of the flock. All birds not illustrated in the figures were dominant to the common cranes.

The flock was more likely to show aggression towards interspecifics than toward members of their own species (Table 5). Males were consistently dominant to female conspecifics. Females were dominant to at least 2 other males interspecifically (Table 6); between species, larger size was also not an assurance of dominance (Table 7). Rank did not appear to be influenced by hatch history. Wild-caught cranes were found both at the top (GB) and bottom (GC) of the hierarchy.

Behaviors Related to Rank

Priority of access to food and water were the activities most clearly related to rank, and strictly followed the dominance hierarchy of the flock. Other crane activities generally associated with rank, such as the stretch-neck-burr (SNB), unison calling, dancing, and nesting, were not as distinct (Table 8).

The SNB display appeared to be more of a function of rank within species and related groups than of rank in the flock. Twelve of the 16 birds performed SNB at least once; frequency of dis-

Table 3. Outcomes of high-intensity dominance interactions. Cranes listed according to rank. Numbers on the ordinate and abscissa refer to the total number of interactions between the indicated individuals (i.e., 2 between GB and RS, 28 between GB and all other birds).

Dominant

Subordinate	GB	RS	WS	NB	GS	BS	S	H	WW	NW	RJ	WJ	BJ	BC	NC	GC	
GB																	0
RS	2																2
WS		5															5
NB	5	4	3				8	1	1								22
GS	2	2	3														7
BS	4	6	1	2	1												14
S			3	1	4												8
H	1	2	4	1	2	3	1			1				2	1	2	20
WW	1	3	2	3	2	2	13	25						6	1		58
NW	10	5	1	9	3	5	3	4	4			1		1		5	51
RJ		1	1		3	1	2	7	7	4							26
WJ	2		1			3	7	7	6	3	4						33
BJ			1		3		1	6	10	1	4	5					31
BC			1	1		1	2		2		2	2	2				13
NC			2	1			3	1			1	1		3			12
GC	1		3	1	1		2		4		1	2		4	3		22
	28	28	26	19	19	15	42	51	34	9	12	11	2	16	5	7	= 324

Table 4. Outcomes of low intensity dominance interactions. Cranes listed according to rank.

Dominant

Subordinate	GB	RS	WS	NB	GS	BS	S	H	WW	NW	RJ	WJ	BJ	BC	NC	GC	
GB																	0
RS			1														1
WS					1												1
NB	6	7	8			1	6	1		1							30
GS	1	1	2	8													12
BS		1	1	6	2												10
S	2	1	2			3											8
H	9	7	5	8	6	6	3			1				1	1	4	51
WW	1	5	3	9	2	9	9				1			3			42
NW	7	6	5	11	5	12	2	7	7				1		2	3	68
RJ	8	4	7		9	7	7	9	12	1							64
WJ	8	6	8		7	4	11	8	7	2	2						63
BJ	7	5	7	1	3	4	9	5	9	1							51
BC	7	2	2	3		3	15	1		1	3	3	6				46
NC	7			6	2	2	6				3	5	7	5			43
GC	5		1	8	2	4	8			2	5	7	2	10	4		58
	68	45	52	60	39	55	76	31	35	9	14	15	16	19	7	7	= 548

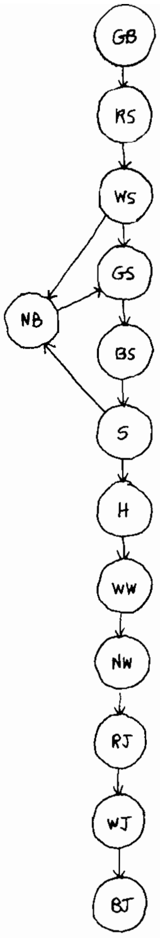

Fig. 2. Model of flock dominance hierarchy, excluding common cranes. Point of arrow indicates subordinate(s).

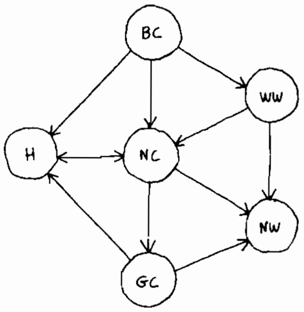

Fig. 3. Dominance hierarchy of common cranes. Not included are those cranes dominant to common cranes. Point of arrow indicates subordinate(s).

Table 5. Incidence of intraspecific versus interspecific aggression in cranes.

Species	Intraspecific aggression	Interspecific aggression
Sarus	18	102
Brolga	5	64
White-naped	4	154
Red-crowned	6	116
Common	8	76

Table 6. Interspecific dominance of female cranes over males.

	Sarus female	White-naped female	Red-crowned female
Sandhill male	x		
Hooded male	x		
White-naped male	x		
Red-crowned males	x	x	
Common males	x		x

play appeared rank-related within the species group *Antigone* (brolga, sarus, and white-naped cranes), and within the hierarchy of the common cranes. SNB was not correlated with dominance in red-crowned cranes where WJ, the 2nd-ranked bird, performed SNB 26 times as opposed to 19 for RJ, the 1st-ranked bird. SNB was displayed most frequently by GB, the dominant male brolga (72). This display was essentially absent in the subordinate brolga NB, the 4 sarus, and the 2 white-naped cranes.

Only 6 members of the flock gave unison calls. These were generally given in response to unison calls of cranes outside of the study area. Among the few instances of unison calling by GB, 1 was given in response to a sarus guard call, and 3 were given after crane personnel had left the enclosure; 2 of these were duets with WS. The 2 male red-crowned cranes called together 7 times (5 times with the mute female who would posture and attempt to call, and twice with S). S most frequently (12 times) unison called by himself. Unison calling did not appear to be rank related with the exception of the territorial defense by GB and WS.

Table 7. Relative size of species and incidence of interspecific dominance of smaller cranes over larger cranes. Number in parentheses designates the species of the individual.

Relative size of species in descending order	Smaller cranes dominant to larger cranes					
(1) Sarus	GB (2)	NB (2)	S (6)	H (7)	NW (4)	WW (4)
(2) Brolga						
(3) Red-crowned	WS (1)	GS (1)	NB (2)	RJ (3)	RJ (3)	RJ (3)
(4) White-naped	RS (1)	BS (1)	RJ (3)	WJ (3)	WJ (3)	WJ (3)
(5) Common	GS (1)		WJ (3)	BJ (3)	BJ (3)	BJ (3)
(6) Sandhill	BS (1)		BJ (3)	WW (4)		
(7) Hooded			WW (4)	NW (4)		
			NW (4)			
			BC (5)			
			NC (5)			
			GC (5)			

Table 8. Frequency of selected behaviors in individual cranes.

	GB	NB	WS	RS	GS	BS	S	H	WW	NW	RJ	WJ	BJ	BC	NC	GC
Stretch-neck-burr	72		2	1			11	28			19	26	1	29	13	10
Dance	3	7	36	7	16	6	4	21	19	23	3	6	4	8	3	7
Nest	2					2	25									
Unison call	4		2				14				7	7	5			

All of the cranes danced, with no apparent correlation to rank. Dancing was displayed in both aggressive and submissive contexts, but never in a reproductive context. GB, RJ, and NC were the least likely to dance (3 times each), and WS the most likely (36 times).

Nesting, the only clear-cut reproductive behavior observed, was performed by 3 birds: S, GB, and BS. S was frequently (25) observed attempting to nest from 25 April until the end of May. These attempts consisted of pulling straw in towards his feet while making low honking sounds. The pen location of this behavior varied. GB, the alpha bird, was 1st observed attempting to nest on 8 May. His behavior consisted of lying on the ground making clucking noises, and pulling straw in towards his breast. During this time he drove off GS, the highest ranking female sarus, but allowed BS to approach closely. GB was next observed nesting on 16 May, closely attended by BS, who purred and gently pulled at BG's back feathers. GB and BS's nesting behavior was not observed again.

Subgroupings Within the Flock

Table 9 shows flocking preferences of individual cranes. Mutual activities, performed within 1-3 m of another bird, ranged from maintenance behaviors to sharing of food and water. The most common flock subgroupings were the dominant brolga GB and any or all of the 4 sarus, the 3 red-crowned cranes, and the 3 common cranes. The 2 brolgas were never observed together, nor were the 2 white-naped cranes. NB, the subordinate brolga, was most often found in the company of NW, a female white-naped (12), and less often in the company of the sarus (8). NW was most frequently

Table 9. Incidence of preferred association of individuals within the flock, e.g., BS and GB were observed in mutual activities on 34 occasions.

	GB	RS	WS	NB	GS	BS	S	H	WW	NW	RJ	WJ	BJ	BC	NC	GC
GB		13	14		20	34				10						
RS	13		18	3	18	16				3						
WS	14	18			23	5										
NB		3			3	2			3	12						
GS	20	18	23	3		4				2						
BS	34	16	5	2	4		2			2						
S						2							2			
H									2				2			
WW				3				2								
NW	10	3		12	2	2										
RJ												41	25			
WJ											41		20			
BJ							2	2			20	25				
BC															18	18
NC														12		12
GC														12	12	
Total	91	71	60	23	70	65	4	4	5	29	61	66	49	24	30	30

in the company of the 2 brolgas (22), and less frequently with the sarus (7). WW was seldom in the company of other birds (5). H and S, both sole representatives of their species, were also loners. S tolerated the presence of the females BS and BJ on 2 occasions each. H allowed WW and BJ to share water with him twice on unusually hot and humid days. The red-crowned cranes generally kept to themselves, except for the female BJ's few instances of sharing with S and H. The common cranes never associated with birds of other species.

DISCUSSION

Dominance or social hierarchies can be found throughout the animal kingdom (Gauthreaux 1978). Dominance rank is generally accepted as the set of sustained aggressive-submissive relations among a group of animals that commonly results in several ranks in a quasi-linear sequence, with occasional triangular or circular elements (Wilson 1975). This definition fails to emphasize the extremely plastic nature of social relationships. Crook (1970) defined social structure as a dynamic system expressing interactions of several factors within the ecological and social milieux that influence spatial dispersal and group tendencies. In other words, social behavior is modified as warranted by the situation.

Dominance hierarchies are thought to be the analogues of territorial behavior, differing in the sharing rather than the parceling out of resources amongst aggressively organized individuals (Gauthreaux 1978). Initially created by aggressive interactions, overt or subtle, the established hierarchy serves to minimize aggression. In his study of Corvids, Lockie (1956) discussed the survival value of dominance hierarchies due to the conservation of energy to both dominant and submissive individuals. If competition developed over a food item, the subordinate could avoid damage, and the dominant win without a fight.

The concept of dominance can be applied broadly. Dominance has been applied to small or large groups of individuals, and even to 2 or more competitive species. Gauthreaux (1978) attempted to classify characteristics that contributed to intraspecific and interspecific dominance hierarchies. Intraspecifically these were: individual characteristics (aggressive interactions create hierarchy within small groups and individual recognition maintains it); class characteristics (supraindividual characteristics that determine and maintain status, e.g., age, sex, size, display); and group characteristics (a social unit, such as a family, group size, or aggression). Factors affecting interspecific dominance were most probably species-specific characteristics, which could be identical to certain class characteristics.

Interspecific dominance hierarchies are often encountered among species belonging to the same taxonomic group. As a rule, the more related and ecologically similar the species, the more pronounced the dominance interactions. Social species forming the largest, best-organized groups tend to dominate others (Wilson 1975). Interspecific dominance hierarchies have been studied in both birds and mammals. Species-specific characteristics were the probable determinants of rank. Morse (1967) found that interspecific hierarchies were formed, feeding niches were narrowed, and dominant birds got the most food in a study of mixed-species flocks of songbirds (nuthatches, warblers, and chickadees).

Cranes embody behavioral scaling, or the adaption of behavior to conditions, when they move from breeding territory to winter flocks. Although I know of no comprehensive studies on dominance in crane flocks in the wild, several captive studies have been conducted. Kepler (1976) delineated a dominance hierarchy within a captive flock of whooping cranes at Patuxent Wildlife Research Center. The birds formed a linear hierarchy, with both individual and class characteristics apparently being the determinants of rank. Archibald (1975) in the course of his Ph.D. studies defined another linear hierarchy within a flock of captive common cranes. Brownsmith (1978) observed interspecific dominance relations between sarus and brolga males at ICF. Brownsmith's observations indicated interspecific dominance of the larger sarus over the brolgas.

The mixed species flock of cranes that I studied at ICF formed a fairly typical dominance hierarchy. The hierarchy was primarily linear, with several aspects of triangularity. Although triangular dominance can be stable (Sabine 1959), more often it is thought to be transitive (Brown 1963). This is probably true of the dominance relationships of the common cranes, who were a major cause of triangularity within the flock.

The complexity of the common crane social relationships, plus their low status within the flock itself, was probably due to their attempting to enter an established hierarchy. Although all members of the flock had been free-ranging over the same 4-ha enclosure before being confined to the quarantine area, the common cranes were never observed associating with the main flock. Therefore, when placed in the small confine with the other birds, they were probably facing an established hierarchy. This phenomenon is termed "social inertia" by Wilson (1975), and he states that any animal that attempts to change its position in a fixed hierarchy is less likely to succeed than if those changes were made during formative stages.

Intraspecific dominance was strictly linear, as is typical for small groups of individuals. Rank was determined primarily through sex (males dominant to females) and individual characteristics (personal courage, energy, and self-assurance). Self-assurance could be a function of prior experience, as in the case of BC, who had been penned with and dominant to a female common-hooded hybrid before being added to the flock in 1978. Age was not a factor intraspecifically, either because conspecifics were all the same age, or as in the case of the white-napes, sex was a greater influence on rank.

Interspecific dominance was more complex, but shared underlying principles. Although species-specific characteristics were important, dominance between species was really determined on an individual basis. Only within the red-crowned cranes were dominance relationships identical interspecifically. These birds, although large, ranked poorly within the hierarchy. Red-crowned cranes have elaborate threat displays (Masatomi and Kitagawa 1975) which serve to minimize aggression between conspecifics. These highly adaptive postures intraspecifically may have harmed them interspecifically, because the other cranes did not threaten in kind but would attack in response.

The high rank of the sarus cranes was undoubtedly due to their large size. Causitive factors in the rank of the brolgas were probably both size and age. Although somewhat smaller than the sarus, GB may have maintained dominance through individual characteristics (self-confidence) coupled with class characteristics. NB was the same size and older than GB, but had a crippled wing that may have affected his confidence, and thus his rank.

Species-specific characteristics are difficult to discuss with a sample size of 1, as was true of the hooded and sandhill cranes. S ranked particularly high. This may have been due to age (he was 4) but more probably due to attitude: he was a supremely confident bird, quite aggressive, with a high rate of success in his encounters (84%). H, although small in stature, was large in spirit. He also was frequently successful (72%) in his aggressive encounters. Other evidence of interspecific dominance encounters among hooded cranes indicate that successful aggression towards larger birds may be a species-specific characteristic. At ICF in 1979, a juvenile hooded crane in a mixed flock of 7 juveniles was dominant to all the birds, including 3 sarus.

Operative factors influencing rank in the common cranes were difficult to detect due to their unusual situation. Their low status may be artificial and could change in the future.

The white-naped cranes played a particularly interesting role within the flock. Although they behaved as a group in their dominance relations (except for interactions with the common cranes) they never associated with 1 another. WW was the most aggressive bird in the flock, with a poor record of wins (38%); a centrally ranked male, the majority of his encounters were with adjacent birds. NW was also involved in many aggressive interactions; however, most (54%) involved high-ranking birds (GB, NB, RS, GS, BS), because she regularly associated with these dominant cranes.

The fact that the cranes were more aggressive interspecifically than intraspecifically may be of adaptive significance. The birds were competing for a finite resource (food and water) so it made sense to fight those cranes with which they did not share genes. Increased interspecific aggression may have also been related to the misinterpretation of behavioral signals for dominance and submission, signals precisely sent and received intraspecifically.

Generally speaking, males are dominant to female conspecifics. Brown (1963) noted a reversal of this in his study of Stellar's jays, but claimed that the female was unusually aggressive and the male unusually docile. Snyder and Wiley (1976) showed female dominance to males in hawks and owls, but this was primarily due to sexual size dimorphism. Within the flock of cranes at the ICF, females were found subordinate to males intraspecifically. Interspecifically, all females were dominant to at least 2 males. Basically, the line of female dominance followed species dominance, i.e., sarus females dominant to all males except for the brolgas and sarus, the female red-crowned crane dominant to the 3 commons (all males), and the female white-naped dominant to the 2 male red-crowned cranes, but not to the common cranes because her dominance relationships were not identical to those of WW.

Some interesting conclusions can be drawn from the crane behaviors listed in Table 8, particularly from the data on SNB. SNB, or bill-raising (Masatomi and Kitagawa 1975) was a behavior that Kepler (1975) found to occur only in his alpha male whooping crane. He also observed it to be correlated with dominance in homosexual pairs of whoopers (1975 pers. comm.). SNB serves both agonistic and precopulatory functions. In the mixed species flock of cranes, SNB was performed either standing or sitting, and seldom appeared to be directed at another bird. It occurred most frequently in the alpha male, GB, but was also present in lesser amounts in most other birds, generally following intraspecific rank; it was not correlated with absolute dominance in the flock itself. Interestingly, it was rare or absent in the sarus, subordinate brolga, and white-naped cranes, although present in significant amounts in all other species. This finding may indicate a suppression of sexual/agonistic behavior by a dominant bird within the species group *Antigone* (sarus, brolga, and white-naped cranes). These birds are believed to be closely related groups of cranes as indicated by similarities in the unison call and comb structure (Archibald 1975). Their behavior within the flock tends to reinforce their relatedness (e.g., all 3 groups tended to flock together), a behavior not observed among the other species of cranes studied. It would be advantageous for a dominant male to repress sexual-aggressive manifestations in birds most closely related to himself (competitors for mates) and to ignore those same behaviors in birds that are distantly related, and thus not competitors for mates. This is what appeared to be occurring within the flock.

The frequency of dancing within the flock lends credence to the theory that it was not a sexual behavior. Dancing was performed by all birds, but most frequently within the sarus and white-naped cranes. Dancing was observed in many contexts. Blankenship (1976) noted dancing as a part of agonistic displays between male whooping cranes on the wintering grounds. Archibald (1975) has observed dancing in an ambivalent context: a crane uncertain whether to fight or flee. And, finally, dancing can be a submissive gesture, imitating the wing-spread of a precopulatory female, and possibly akin to rump-presenting in primates. This multiplicity of behavioral interpretations explains why dancing was poorly correlated with dominance.

Unison calling is an agonistic behavior used in formation of pair bonds and in territorial defense. Within the flock, S most frequently unison called, in keeping with his aggressive nature and high rank. The 3 red-crowned cranes also tended to unison call despite their low status. This behavior may be correlated with their role in the flock of common territorial defense via threat postures if a crane caretaker enters the enclosure. However, it was the dominant male GB, sometimes in concert with WS, who unison called after the intruders left. GB, a wild-caught bird, avoided encounters with humans, which perhaps prevented him from playing the role of territorial defense observed in a dominant male whooper (Kepler 1976), and limiting him to territorial defense after the fact.

The nesting behavior of GB and BS has already been described. BS actively sought the company of GB before and following those behaviors, in preference to all other birds (52% of her flocking encounters). Although not always tolerated, BS would frequently refuse to leave GB's side when threatened, merely stopping her behavior and assuming a submissive posture (neck retracted, neck feathers ruffled). On 3 occasions BS was observed allopreening GB; 2 of these actions were tolerated. Twice GB appeared to direct SNB behavior towards BS. All this evidence indicates possible pair formation between the dominant male brolga and the 2nd ranking sarus female. This is particularly interesting in view of the hybridization that has been observed between the 2 species in the wild. It remains to be seen whether these birds will actually mate.

Common subgroups within the flock followed species or species-group lines. Hand-reared birds such as the sarus and red-crowned cranes formed intraspecific subgroupings despite the lack of a parental model. The sandhill crane had no member of his species with which to associate. The hooded crane was also solitary, but had been frequently observed in the vicinity of a juvenile hooded crane that was being temporarily housed in the barn. The white-naped cranes never associated with each other. Unlike the sarus and red-crowned cranes, they also had different hatch years, which may or may not have been an influence. Chicks of the same hatch year, although physically separated, were often in visual contact with members of their species. The white-naped cranes did associate with other cranes within the species group *Antigone*. This was true of NW, the female, more than WW. The common cranes, wild-caught birds, associated with each other and no other cranes. The 2 brolgas never associated with each other, but both associated with the sarus and NW. The intolerance of a dominant male towards a 2nd-ranked male conspecific has been documented by Lorenz (1952).

CONCLUSIONS

It has been demonstrated that a mixed species flock of cranes will form a dominance hierarchy. These hierarchies are directly related to priority of access to food and water. Captive management should allow a sufficient number of food and water sources to prevent stress to low-ranking birds. Wild populations of sympatric cranes may result in a narrowing of feeding niches. In captivity, sexual behavior may be suppressed in subordinates of species groups as well as between conspecifics; therefore, closely related species should not be grouped together as adults if they are later to be used as breeders. Sexual behavior between a male brolga and a female sarus underscores the problem of hybridization within sympatric Australian populations. Hand-reared birds of the same species tended to flock together as adults. This may indicate an innate recognition of conspecifics, or be related to conditions of rearing.

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WEIGHT LOSS OF CRANE EGGS

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Abstract: Weight losses were analyzed for artificially incubated red-crowned (*Grus japonensis*) and white-naped crane (*G. vipio*) eggs. There was no significant difference in the weight lost by eggs in different states of fertility. No strong correlations were found between the percent weight loss of eggs and the initial egg weight for either species. The egg's initial weight did not affect hatchability. Most eggs lost 12 to 16% of their initial weight during incubation. Red-crowned eggs decreased in hatchability as the percent of weight loss increased from 10 to 16%. The opposite was true of white-naped eggs which increased in hatchability as percent weight loss increased from 10 to 16%. Weight loss data from wild and captive sandhills (*G. canadensis*) eggs are similar.

INTRODUCTION

A specific percentage of an egg's initial weight is lost during incubation. This weight is lost as water passively diffuses through the egg's microscopic pores. Drent (1975) and Rahn et al. (1979) have found that eggs lose 15-18% of their initial weight. This weight is dependent on several variable factors: temperature, humidity, air speed around the egg, and the shell's morphology (Rolnik 1970). During natural incubation the relationship between these factors changes often and varies in each species. It is necessary to manipulate these factors during artificial incubation in order to achieve a high hatchability rate. The mechanisms behind this weight loss are not clearly understood. This study examines weight loss data from the International Crane Foundation (ICF) and from wild sandhill cranes (*G. c. tabida*).

I wish to thank Karen Voss for her aid in finding the wild sandhills, Mr. Wilcox for allowing us to use a blind on his property, Rick Norbheim for his statistical consulting, a special thanks to Curt Baumann for trudging through the marshes to collect data, and to Theresa Coffey for helping with final touches.

METHODS AND MATERIALS

ICF has been artificially incubating crane eggs for the past 6 years. I analyzed weight loss data from the eggs artificially incubated at ICF (1976-81). The analysis of data is divided into 3 sections: (1) variability of the total percent weight loss for crane eggs in different states of fertility (i.e., fertile hatched=FH, fertile dead=FD, infertile=I), (2) possible correlations between the total percent weight loss and initial weight of red-crowned and white-naped eggs, (3) possible factors affecting hatchability--(a) initial egg weight and (b) total percent weight loss. Section 1 was analyzed using a 1-way analysis of variance (ANOVA) with unequal sample sizes. Because the sample sizes are small it is only possible to look for general trends in the data.

Weight loss data were collected from wild sandhill cranes nesting at French River Creek Wildlife Area in Columbia County, Wisconsin. Twelve behavior observations were made from 24 March to 28 April, between 0600-0800 hours. Several groups of paired and unpaired cranes were observed and nest sites were located with a 15X spotting scope and 7x35 field binoculars. Changes in behavior were used to calculate the onset of incubation. I weighed the eggs 1 week after they were laid using a triple beam balance. Because many nests were inaccessible I was only able to monitor 2 nests. Each egg was weighed once a week until hatching. From this data the egg's total percent weight loss was calculated and compared with the weight loss data of artifically incubated sandhill crane eggs.

RESULTS AND DISCUSSION

Variations in Total Percent Weight Loss

The following data are from eggs artifically incubated at ICF (1976-80). ANOVA tests were used to calculate correlations in total percent weight loss between (1) breeding years, (2) individual cranes, and (3) species in the different states of fertility (FH, FD, I).

The 1st ANOVA tests examine possible variations in the total percent weight loss for breeding pairs of individual cranes (same species). There is not a significant variation ($P > 0.01$) between

Table 1. One-way ANOVA for the total percent weight loss of FH and I eggs from individual red-crowned cranes, 1976-80.

Categories and female	N	Mean	St. Dev.	F-ratio	P-value
FH eggs					
Zhurka	11	12.5	1.54	3.89	0.01 < P < 0.05
Lulu	6	12.1	2.14		
Sauwaka	2	15.9	0.85		
I eggs					
Zhurka	10	12.6	1.75	1.45	P > 0.01
Lulu	2	11.1	2.47		
Sauwaka	2	14.1	0.64		

Table 2. One-way ANOVA for the total percent weight loss of I eggs from individual white-naped cranes during specific years.

Categories and female	N	Mean	St. Dev.	F-ratio	P-value
I eggs					
Bette					
1980	2	12.5	1.48	4.87	0.01 < P < 0.05
1979	8	11.5	1.17		
1976	3	9.6	0.50		

years for red-crowned eggs (Table 1). However, there was a significant variation between breeding years for white-naped crane eggs (Table 2). This variation is expected due to changes over the years in management practices for white-naped eggs. From 1976-79 white-naped eggs failed to lose enough weight. This indicated that the incubator humidity was too high for the eggs. To correct this, in 1980 all white-naped crane eggs were moved to a lower humidity incubator. The results of this change can be seen in the higher white-naped egg weight losses from 1980 to present and the insignificant ($P > 0.01$) results of variance tests that compare the weight loss of FH, FD, and I eggs between white-naped and red-crowned cranes.

Sauwaka, a red-crowned female, consistently produced eggs with significantly higher weight losses (Table 1). This difference is probably due to some variation in her egg's shell morphology (i.e., pore geometry or eggshell thickness). Variation in an eggshell's thickness can be due to an individual female's physiology or her genetics (Klass et al. 1974, Hoffman 1978). This is a possible explanation for the observed variations in Sauwaka's eggs. In 1981 she produced 1 fertile egg that lost 21% of its initial weight and from which the chick died shortly after being helped from its shell.

Rolnik (1970) and Murray (1925) report a change in the percent weight loss of a hen's egg after the 16th day of incubation. The increase in weight loss is attributed to changes in embryo metabolism and thinning of the eggshell. This means the change is only seen in fertile eggs. Rahn and Ar (1974) and Rahn et al. (1979) have determined that eggs lose weight at a constant rate that is independent of the embryo's metabolism. This loss is regulated by the shell's morphology.

Weight losses for red-crowned and white-naped crane eggs do not vary significantly among eggs of differing states of fertility (Table 3). Sheppard (1980) found similar results with white-naped eggs at the New York Zoological Park (Bronx Zoo). If the weight loss of an egg was dependent on the embryo's metabolism, there would have been a significant difference in weight loss between FH, FD, and I eggs. It has also been observed that eggs at ICF lose weight in a constant and linear rate. Data from Sheppard (1980) and Table 3 support the physiological theories of avian egg weight loss discussed by Rahn and Ar (1974) and Rahn et al. (1979).

From 1976-79, eggs at ICF and the Bronx Zoo were incubated under the same conditions (37.6° C and 59% relative humidity). Despite these

Table 3. One-way ANOVA for the total percent weight loss of red-crowned and white-naped cranes between FH, FD, and I eggs, 1976-80.

Categories	N	Mean	St. Dev.	F-ratio	P-value
Red-crowned cranes					
FH	19	12.7	1.98	0.34	P < 0.01
I	14	12.6	1.82		
FD	3	13.6	1.17		
White-naped cranes					
FH	3	12.5	5.28	0.19	P < 0.01
I	15	11.5	2.10		
FD	3	11.9	1.11		
White-naped cranes[a]					
FH	8	17.3			
I	5	16.6			
FD	6	16.6			

[a] Sheppard (1980).

similarities white-naped eggs from ICF lost significantly less weight (Table 3). After the humidity change in 1980 the difference has been decreased, yet still exists. There must be other factors affecting these eggs which explain these variations.

Drent (1975) found a positive linear relationship between the daily water loss and the initial weight of an egg. Rahn et al. (1979) took this 1 step further and plotted the total amount of water lost during incubation against the initial weight of an egg. They showed that by the end of incubation all eggs loose approximately 15% of their initial weight. From this information Drent (1975) found a direct relationship between each egg's initial weight, incubation period, shell morphology, and total percent weight loss. These relationships are seen in the eggs artificially incubated at ICF (Figs. 1 and 2). Regardless of their initial weight all eggs are incubated either at 37.6°C and 59% relative humidity or 37.6°C and 49% relative humidity. Most eggs lose 12-16% of their initial weight (Figs. 3 and 4).

The factors affecting hatchability are important for institutions artificially incubating eggs. I examined 2 factors, initial egg weight and total percent weight loss, that could affect hatchability. Figures 3 and 4 illustrate the relationship between hatchability and the initial egg weight for white-naped and red-crowned eggs. Figure 3 indicates that there is no correlation between the initial weight and hatchability of white-naped eggs; red-crowned eggs (Fig. 4) show a slight trend toward decreased hatchability with size. The significance and implications of this decrease are unclear.

Robertson's (1961) and Rolnik's (1955) data support the view that there is no correlation between percent weight loss and percent hatchability. However, Hays and Spear (1951) believe there is a correlation. Figure 5 shows a decrease in hatchability of red-crowned eggs as the percent weight loss increases. The exception is the entry at 16-18% weight loss which is an egg from Sauwaka whose eggs normally have a high percent weight loss. Without the latter entry the trend is clear. Figure 6 shows an increase in hatchability of white-naped eggs as the percent weight loss increases. The entries for 1976-79 deviate from this trend because white-naped crane eggs were then incubated at 59% relative humidity.

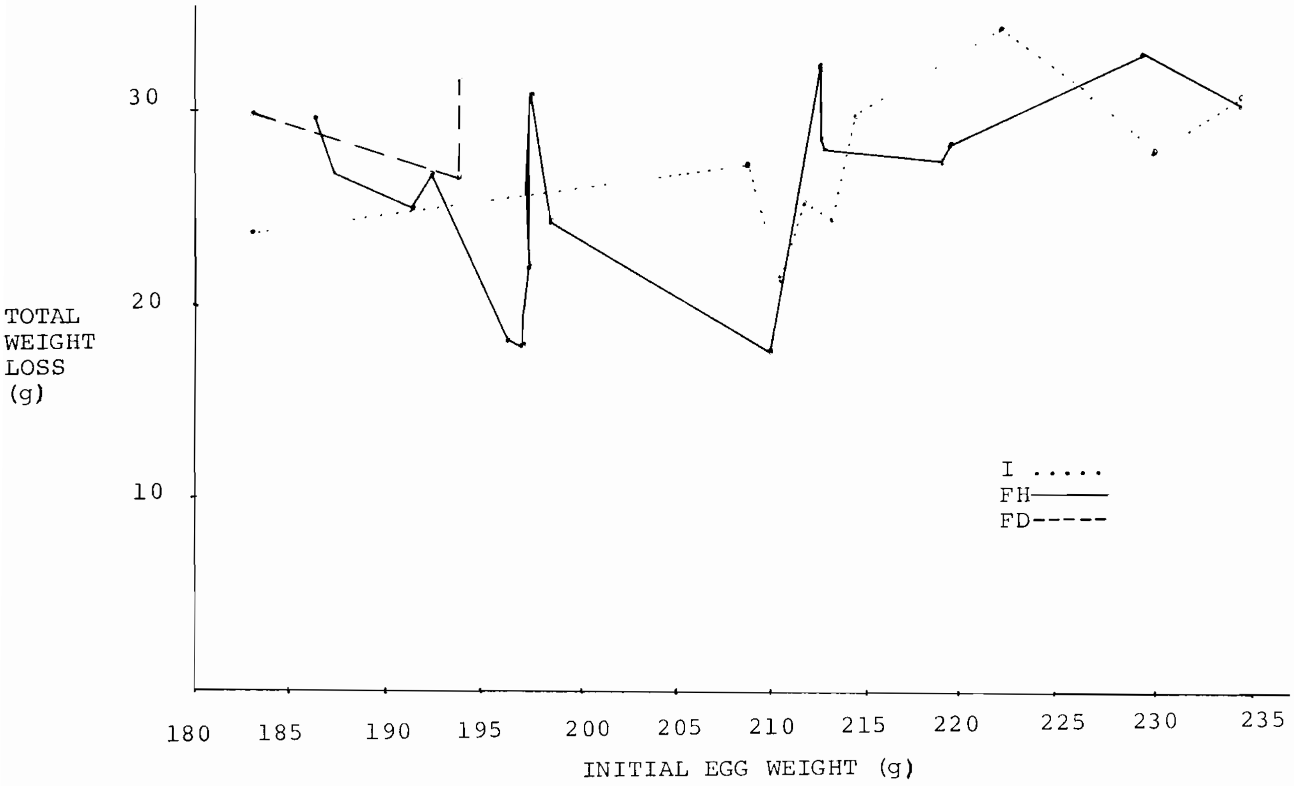

Fig. 1. Total weight loss versus initial egg weight for red-crowned cranes.

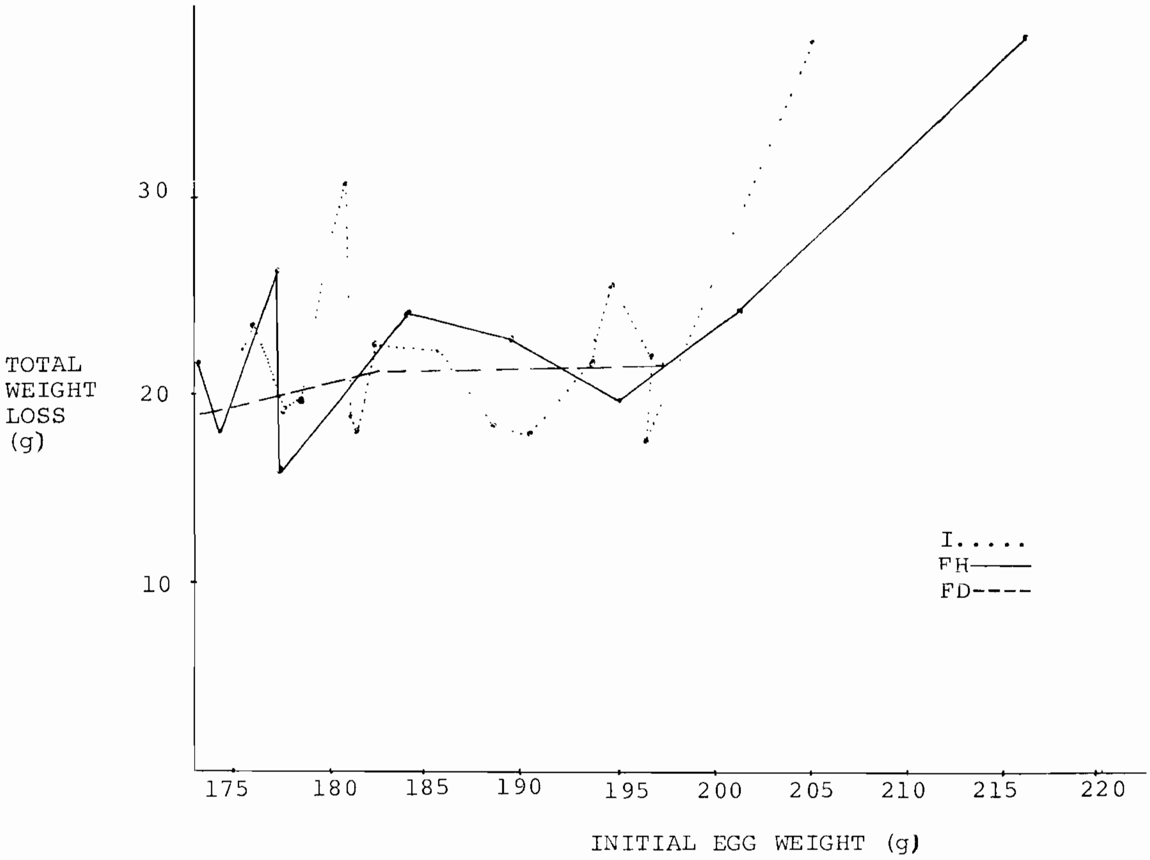

Fig. [illegible]. Total weight loss versus initial egg weight for white-naped cranes.

The red-crowned eggs show a decrease in hatchability as weight loss increases from 10 to 16 , while white-naped eggs show an increase in hatchability between this weight loss range. Note also that the greatest number of red-crowned and white-naped eggs lose weight within the 12-14 range. These and other data suggest that there are differences between the incubation requirements for white-naped and red-crowned cranes. This year's hatchability rates for white-naped and red-crowned eggs have increased noticeably. The eggs are losing weight within the same range but with a higher hatchability. This suggests the importance of other variables in the successful hatching of eggs.

I collected weight loss data from wild sandhills to determine if our range of weight losses for artificially incubated eggs is within the range of wild cranes. This was the 1st year I attempted to collect data from wild sandhills and I was only able to monitor 4 eggs. The percent weight losses from wild sandhills and captive sandhills appear to be similar (Table 4). This indicates that ICF's artificial

Table 4. Total percent weight loss for wild and captive sandhill eggs, 1981.

Eggs	Percent weight loss	Fertility
Wild	12.9	F
	13.4	F
	13.7	?
	18.5	?
Mean	14.6	
Captive	15.4	F
	13.4	F
	13.0	F
	12.8	I
	14.2	I
	17.6	I
	22.1	I
Mean	15.5	

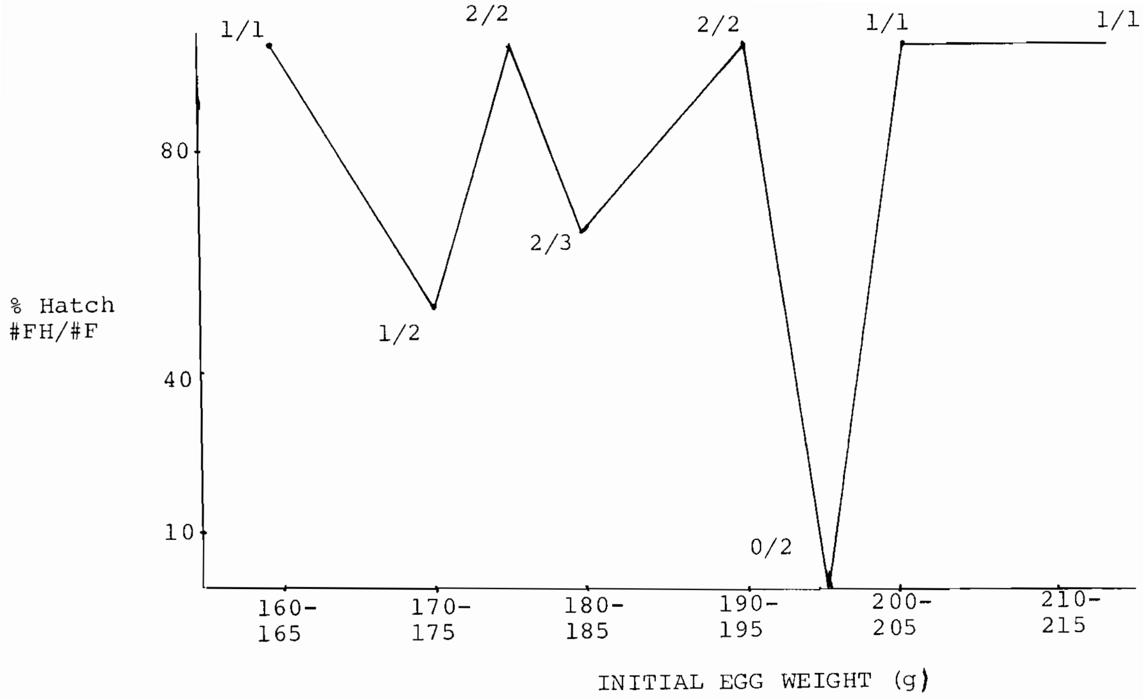

Fig. 3. Percent hatchability as related to initial egg weight for white-naped cranes, 1976-1981.

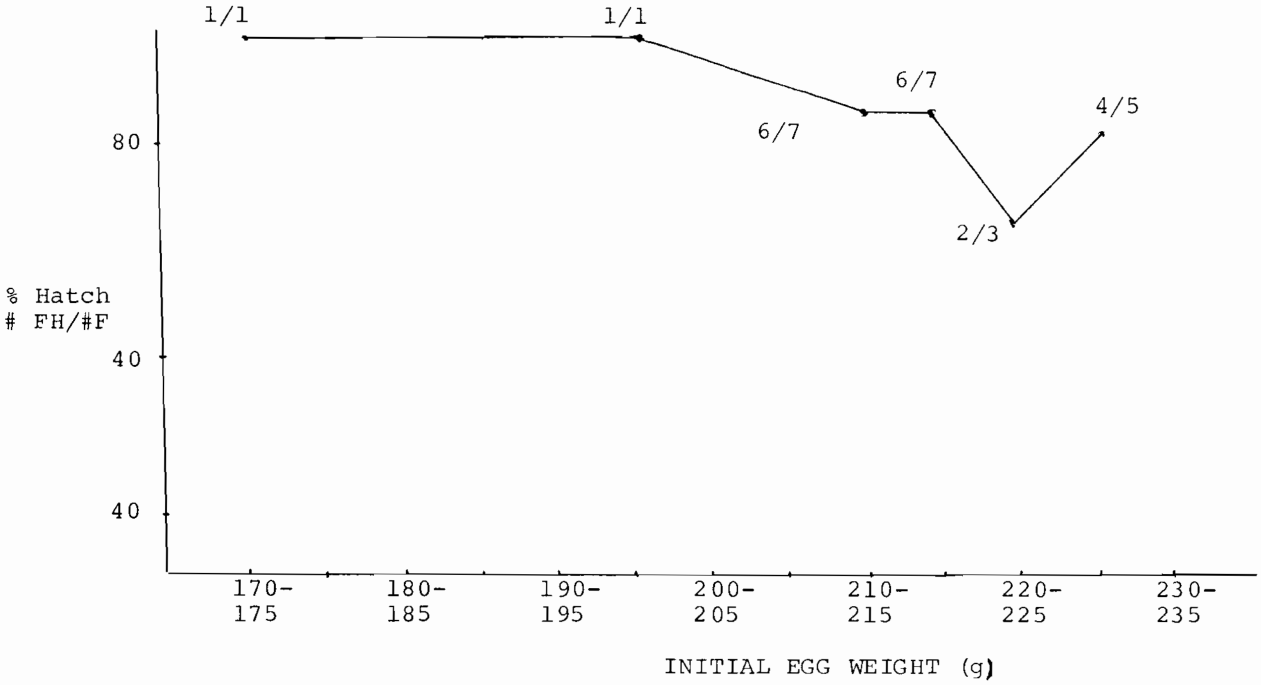

Fig. 4. Percent hatchability as related to initial egg weight for red-crowned cranes, 1976-1981.

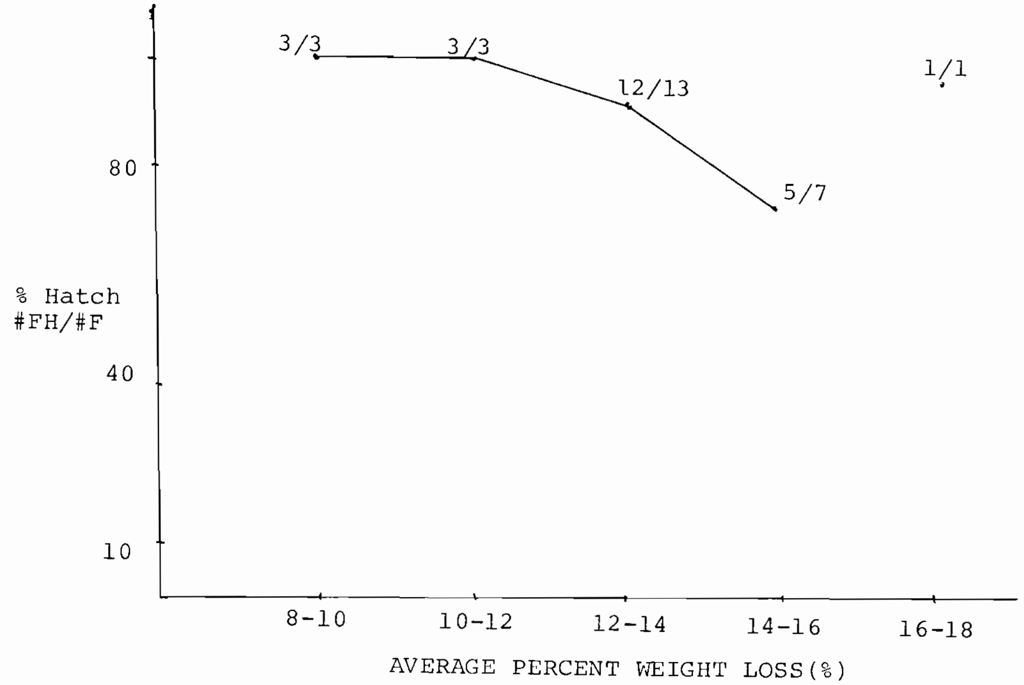

Fig. 5. Correlation between percent hatchability and average percent weight loss for red-crowned eggs, 1976-1981.

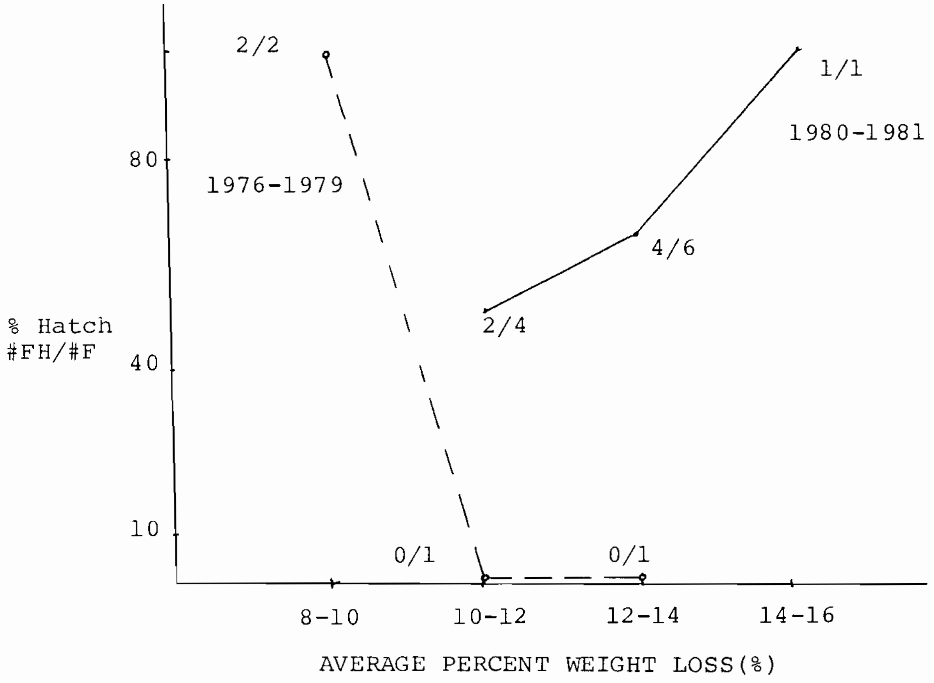

Fig. 6. Correlation between percent hatchability and average percent weight loss for white-naped eggs, 1976-1981.

incubation temperatures and humidities are within the proper range for sandhills but more data needs to be collected.

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HORMONAL TREATMENT AND FLIGHT FEATHER MOLT IN IMMATURE SANDHILL CRANES

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Abstract: Molt, the production of a new generation of feathers, is a poorly understood physiological phenomenon in nondomestic birds. Often in large birds like geese, flight is restricted by clipping the primary remiges on 1 wing and flight is restored after the molt when the primaries are replaced. A similar technique would be desirable for use with cranes conditioned for release to the native habitat. However, immature sandhill cranes (*Grus canadensis*) did not appear to replace their primaries annually; therefore, we studied their flight feather molt (from 4 months to 3.5 years of age) and attempted to influence molting. Under natural conditions tail feathers (rectrices) were replaced annually and all secondaries replaced in 2.5-year-old birds. However, replacement of primaries in immature sandhill cranes appears to be a gradual process beginning the 2nd year; about 33% of the original primaries (present at 10 months of age) persisted in the 3.5-year-old birds. Pulling out the primaries of immature sandhill cranes induces the growth of new primaries, as is true of many other birds. However, the new primaries were incapable of supporting flight, fell out repeatedly, and those that remained were often deformed. Pulling the primaries, under the influence of tranquilizers and anesthetics to relax the feather papillae, also did not induce normal growth of the replacement primaries. Progesterone (including excessively high doses), thyroxine, and follicle stimulating hormone, although effective in inducing feather replacement in domestic poultry, had no effect on crane molt.

Molt is defined as the process whereby birds periodically lose and replace their plumage, outermost layers of skin, and other integumentary derivatives (Pettingill 1970, Lucas and Stettenheim 1972, Palmer 1972). It is believed that the process of feather loss is passive; new feathers pushing old ones from their feather follicles in a defined manner (Watson 1963). These waves of feather growth (rates of feather loss vary, accelerate and subside, and progress from 1 feather tract to others) are related to the reproductive cycle, age of the bird, and the degree of molt (Pettingill 1970, Lucas and Stettenheim 1972, Palmer 1972). Feather renewal appears to be under both endocrine and spontaneous, cyclical control of the feather papillae (Juhn 1963). However, the "fright phenomenon," the casting of feathers when birds are handled or streesed, is still largely unexplained (Stettenheim 1972, Ree 1973). The gonadal steroids and several hypophyseal, thyroidal, and adrenal hormones have been implicated in the control of feather growth (Payne 1972). Although molt can be induced without using endocrine products, most methods for inducing molt affect endocrine function (Anonymous 1955, Farner 1961, Ishigaki et al. 1972, Gavrilov 1974, Boersma 1975).

Management of large captive birds requires methods of restricting or controlling flight without excessively confining physical activity. Often birds are rendered flightless by pinioning, tenotomy, tenectomy, or use of wing brails (restraints)(Miller 1973). However, wings of those intended for introduction to the wild must be managed in a way which will not interfere with their ability to fly when released. The primaries of 1 wing can be trimmed back to the tips of the coverts to restrict flight. When desired, flight capability is quickly restored to most birds by pulling out the shortened primaries. Generally, new feathers are in place in less than 8 weeks (Griswold 1974). However, we found that pulling shortened primaries from sandhill cranes to induce new feather growth was unsatisfactory because replacement occurs unpredictably over as long as 3 years. Thus, our young cranes raised for release must be held in large, relatively expensive covered pens so that they will be able to fly when released.

Lack of a clear understanding of molt and feather replacement patterns in cranes and factors influencing them has hindered the development of less expensive methods for controlling flight of captive cranes. Several reports state that cranes may molt in any single year (1) all primary remiges, (2) all secondary remiges, (3) some of 1 and all of the others, and (4) some of 1 and none of the others (Walkinshaw 1949, Littlefield 1970, Drewien 1973, Lewis 1974). Most reports concerning crane molt are based upon the examination of live wild birds or museum specimens. Ages of these birds and their reproductive condition were estimated because actual and reproductive history were unavailable. In a recent study of live birds and museum specimens, Lewis (1979) reported that cranes do not replace all remiges annually or even in alternate years. He found crane wings bearing primary feathers with as many as 3 different ages. Because of this incomplete information concerning feather replacement in immature sandhill cranes and the need for a better way of restricting flight of captive cranes, studies were undertaken with captive immature sandhill cranes to examine the sequence of flight feather replacement and to explore procedures for inducing replacement of remiges and rectrices.

MATERIALS AND METHODS

Two flocks of 30 immature sandhill cranes each were randomly divided into 5 groups for 3 years to study the effects of hormone treatment upon flight feather molt and to observe flight feather replacement. Flock 1 (10-month-old birds) was treated with hormones in the spring and Flock 2 (3-month-old birds) was treated with hormones in the fall. Each flock was held in a 96- x 96-m field equipped with automatic waterers and gravity-flow poultry feeders. The flight feathers on all birds were identified by tattoo using a combination of dots and colored dyes. The primaries on the right wing of all birds were removed 1 week after the start of the study. Each group of 6 birds was randomly assigned to 1 of 5 experimental treatments and identified with color-coded, numbered leg bands within each flock.

Group 1 was treated with intramuscular (IM) injections of thyroxine[1] plus progesterone[2], group 2 with IM injections of progesterone, group 3 with subcutaneous (SQ) injections of progesterone at the base of the primaries, group 4 with IM injections of progesterone plus IM injections of follicle stimulating hormone[3] (FSH), and group 5 served as untreated controls (Table 1).

Table 1. Hormone treatments used in an attempt to induce molt in captive immature sandhill cranes.[a]

Group[b]	Treatment	Dosage[c]	Time of injection
1	Thyroxine	14 mg IM breast	Start of study
	Progesterone	80 mg IM breast	7 days after start of study
		80 mg IM breast	14 days after start of study
2	Progesterone	80 mg IM breast	7 days after start of study
		80 mg IM breast	14 days after start of study
3	Progesterone	80 mg SQ, multiple injections at base of primaries, 40 mg per wing	7 days after start of study
		Repeat above	14 days after start of study
4	Progesterone	80 mg IM breast	7 days after start of study
	FSH	20 mg IM breast each day	7, 8, 9, 10, 11, and 12 days after start of study
	Progesterone	80 mg IM breast	14 days after start of study
		20 mg IM breast each day	14, 15, 16, 17, 18, and 19 days after start of study
3	Untreated controls		

[a] Flocks consisting of 10-month-old and 3-month-old sandhill cranes were used for this work.

[b] Primaries on right wing pulled out 7 days after start of study in all 5 groups.

[c] Dosage rates (mg/kg body weight) were similar to those used with domestic poultry and some other nondomestic species (Harris 1956, Juhn 1963, Ringer 1965, Payne 1972).

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[1] No. 14666 L-(-)Thyroxine. Fisher Scientific Co., 711 Forbes Ave., Pittsburgh, PA 15219. Mention of commerical items does not constitute endorsement of the item by the author or the U.S. Fish and Wildlife Service.

[2] Repository Progesterone, 50 mg/ml. Darby Drug Co., Inc., 100 Banks Ave., Rockville Center, NY 11571.

[3] Repository FSH, 50 mg/ml. Darby Drug Co., Inc., 100 Banks Ave., Rockville Center, NY 11571.

The flight feathers on each bird were examined beginning the 5th week of the study in each flock, every 2nd week for the next 4 months, and each fall for the next 2 years. The birds were observed for anatomical and behavioral abnormalities. Records were maintained on new undyed feathers that replaced marked or removed feathers on each crane.

RESULTS AND DISCUSSION

Immature sandhill cranes required 1 year or longer to replace their rectrices, required more than 2 years to replace secondaries, and more than 3 years to replace all primaries (Table 2). The rectrices were replaced during the summer and early fall months. The order of tail feather replacement (from the outside in or from the center out) was unclear because some rectrices were accidentally lost during handling. A few new secondaries were discovered during the 1st and 2nd years (possibly replacement of feathers lost during handling). The secondaries nearest the body were the 1st to be replaced, singularly, or in groups of several feathers. A few primaries were replaced in birds that had reached 2 years of age and more than 66% of the primaries were replaced in birds that had reached 3 years of age. However, none of the birds in this study (17 in excess of 3 years old) replaced all their postjuvenal primaries. There was a tendency for primaries over the distal radius-ulnar to be replaced before those farther out on the wing. New feathers were often separated by 1 or more of the old primaries; consequently, molt of the primaries did not proceed in any clearly defined order.

Table 2. Flight feather molt (postjuvenile feathers replaced[a]) in immature sandhill cranes.

Age (months)	Number birds[c]	Right wing[b]			Left wing	
		Number primaries[d]	Number secondaries	Number rectrices	Number primaries	Number secondaries
Flock 1[e]						
11	30	5.8 ± 3.3	0	0	0	0
13	30	5.2 ± 2.5	0.9 ± 1.5	3.7 ± 2.2	0.1 ± 0.4	0.7 ± 1.7
28	21	6.7 ± 3.5	19.9 ± 0.3	12.0 ± 0.0	2.9 ± 2.2	17.8 ± 5.2
38	17	6.3 ± 3.2	20.0 ± 0.0	12.0 ± 0.0	8.1 ± 2.3	20.0 ± 0.0
Flock 2[f]						
4	30	4.4 ± 3.1	0	0	0	0
6	28	4.5 ± 2.9	0	0	0	0
16	21	6.0 ± 3.0	3.4 ± 2.6	11.1 ± 2.7	0	2.8 ± 2.9
28	19	6.3 ± 3.4	20.0 ± 0.0	12.0 ± 0.0	2.4 ± 2.6	20.0 ± 0.0

[a] Sandhill cranes have 10 primary and 20 secondary remiges, and 12 rectrices. Feathers replaced at time of inspection.

[b] Primaries on right wing removed 7 days after start of study.

[c] Mortality was greater than anticipated due to an extraintestinal coccidial infection.

[d] Replacement primaries deformed, lost repeatedly throughout study.

[e] Ten months old at beginning of experiment.

[f] Three months old at beginning of experiment.

Investigators of sandhill crane molt report a partial to complete replacement of flight feathers annually (Walkinshaw 1949, Littlefield 1970, Drewien 1973, Lewis 1974). Lewis (1979) reported primaries of 3 different ages on the same wing of some sandhill cranes, possibly 3- or 4-year-old sandhills as in this study. Assuming cranes molt all primaries annually after they are 4 years of age, birds observed with all new primaries should either be less than 2 years of age or adults more than 4 years old. Cranes with primaries of 2 ages would most likely be 2 to 3 years old, and those with primaries of 3 ages would likely be 3 to 4 years old. A study similar to our study with adult breeders and nonbreeders (4 or more years old) should be conducted.

Pulling primaries from the right wing of each of our cranes induced growth of new primaries; however, the replacement feathers were abnormal. Replacement feathers varied in form from a bloody stump or deformed quill to a nearly normal primary. The majority of the primaries on the right wing were lost and replaced repeatedly throughout the study; some of the primaries were still missing, and others were still deformed 2.5 years after the original feathers were removed. In Flock 1, an average of 6.7 primaries was replaced through natural processes on the left wing. In Flock 2, an average of 6.2 feathers was replaced 1 year after the originals were removed and before any were replaced through the natural processes on the opposite wing.

The number of flight feathers replaced in hormone-treated sandhill cranes was similar to the number that were replaced in untreated controls (Tables 3 and 4). Although not part of this study, no unusual feather loss was noted from other parts of the body in the hormonal-treated groups (1-4). The numbers of primary and secondary feathers on the left wing and secondaries on the right wing (sum of data from Tables 3 and 4) replaced during the 3 months following treatment were small: 8 in group 1, 2 in group 2, 10 in group 3, 2 in group 4, and 9 in group 5 (control). Also, hormone treatment did not appear to influence replacement of primaries removed from the right wing (sum of data from Tables 3 and 4) during the 3 months following treatment: 66 in group 1, 57 in group 2, 56 in group 3, 37 in group 4, and 66 in group 5. Although the hormones used did not induce molting in sandhill cranes, their use at similar dosages has been reported to induce molt in domestic poultry and some other birds (Harris 1956, Ringer 1965, Payne 1972). The crane appears to be another of many nondomestic birds that do not molt in response to some exogenous hormones (Harris 1956, Payne 1972).

In a related study at Patuxent, in an attempt to relax feather papillae and reduce the trauma in removing the primaries, tranquilizers and anesthetics were administered to cranes previously administered a high level of progesterone (2,300 mg in 7 weeks). The use of the relaxing agents showed some marginal improvement in the number of "normal appearing" replacement primaries, but large doses of progesterone were as ineffective as those used in this study.

SUMMARY AND CONCLUSION

Methods to restrict flight of cranes usually render the birds flightless for life (e.g., pinioning) or for prolonged periods (e.g., trimming primaries to tips of coverts on 1 wing), or require propagation in covered pens. A method is needed to induce the rapid replacement of flight feathers in sandhill cranes.

Treatment with progesterone, thyroxine, and FSH (all known to induce molt in some other birds) failed to induce molt of flight feathers in immature sandhill cranes at the Patuxent Center. Mechanical removal of primary feathers resulted in abnormal feather development in their place.

It is possible that feather removal by pulling could be modified with the use of agents to relax the feather follicle and reduce trauma to the germinal tissues, to permit replacement by normal primaries. There appears to be no satisfactory method for controlling flight of captive cranes utilizing the process of molting and feather replacement. There appears to be no practical alternative to large covered pens for raising immature sandhill cranes destined for release in their native habitat.

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Table 3. The lack of hormonal effect on flight feather molt (postjuvenile feathers replaced) in immature sandhill cranes of Flock 1.[a]

		Right wing[b]			Left wing	
Age (months)	Number birds[c]	Number primaries[d]	Number secondaries	Number rectrices	Number primaries	Number secondaries
Group 1: Progesterone and thyroxine						
11	6	7.7 ± 2.9	0	0	0	0
13	6	5.7 ± 1.7	0.3 ± 0.8	3.7 ± 2.0	0	1.0 ± 2.4
28	4	7.8 ± 1.7	20.0 ± 0.0	12.0 ± 0.0	4.0 ± 4.9	19.5 ± 1.0
38	3	7.0 ± 3.0	20.0 ± 0.0	12.0 ± 0.0	6.7 ± 3.0	20.0 ± 0.0
Group 2: Progesterone						
11	6	7.0 ± 2.0	0.2 ± 0.4	0	0	0
13	6	5.0 ± 3.3	0.2 ± 0.4	4.5 ± 1.4	0	0.2 ± 0.4
28	5	6.4 ± 4.3	18.6 ± 0.5	12.0 ± 0.0	2.8 ± 1.3	19.8 ± 0.4
38	4	7.8 ± 1.7	20.0 ± 0.0	12.0 ± 0.0	8.8 ± 1.9	20.0 ± 0.0
Group 3: Progesterone - SQ						
11	6	3.2 ± 3.1	0	0	0	0
13	6	6.7 ± 2.3	1.3 ± 1.7	3.8 ± 2.7	0	0.3 ± 0.5
28	4	5.2 ± 3.6	20.0 ± 0.0	12.0 ± 0.0	4.5 ± 1.9	20.0 ± 0.0
38	3	4.3 ± 2.5	20.0 ± 0.0	12.0 ± 0.0	8.0 ± 4.0	20.0 ± 0.0
Group 4: Progesterone and FSH						
11	6	4.5 ± 2.7	0	0	0	0
13	6	3.3 ± 2.2	0.3 ± 0.8	3.8 ± 2.6	0	0
28	5	6.2 ± 4.8	20.0 ± 0.0	12.0 ± 0.0	3.0 ± 2.4	12.2 ± 9.7
38	5	6.8 ± 4.6	20.0 ± 0.0	12.0 ± 0.0	7.2 ± 2.9	20.0 ± 0.0
Group 5: Control						
11	6	6.7 ± 3.8	0.8 ± 1.6	0	0	0
13	6	5.2 ± 1.7	0.5 ± 1.2	2.7 ± 2.6	0.3 ± 0.8	0.5 ± 1.2
28	4	8.0 ± 3.4	20.0 ± 0.0	12.0 ± 0.0	5.8 ± 5.0	17.8 ± 2.6
38	2	4.0 ± 1.4	20.0 ± 0.0	12.0 ± 0.0	8.5 ± 2.1	20.0 ± 0.0

[a] Flock was 10 months old at beginning of study. Feathers replaced at time of inspection.

[b] Primaries on right wing removed 7 days after start of study.

[c] Mortality was greater than anticipated due to an extraintestinal coccidial infection.

[d] Replacement primaries deformed, lost repeatedly throughout study.

Table 4. The lack of hormonal effect on flight feather molt (postjuvenile feathers replaced) in immature sandhill cranes of Flock 2.[a]

		Right wing[b]			Left wing	
Age (months)	Number birds[c]	Number primaries[d]	Number secondaries	Number rectrices	Number primaries	Number secondaries
Group 1: Progesterone and thyroxine						
4	6	6.7 ± 3.5	0	0	0	0
6	5	6.4 ± 2.4	0.2 ± 0.4	0	0	0
16	4	8.5 ± 1.7	5.5 ± 3.3	12.0 ± 0.0	0	2.5 ± 2.9
28	3	9.0 ± 1.0	20.0 ± 0.0	12.0 ± 0.0	3.7 ± 3.2	20.0 ± 0.0
Group 2: Progesterone						
4	6	4.8 ± 2.6	0	0	0	0
6	5	5.4 ± 2.4	0	0	0	0
16	5	6.4 ± 1.8	3.6 ± 2.5	10.2 ± 4.0	0	2.6 ± 3.7
28	5	6.4 ± 2.3	20.0 ± 0.0	12.0 ± 0.0	1.6 ± 2.5	20.0 ± 0.0
Group 3: Progesterone SQ						
4	6	2.8 ± 3.1	0	0	0	0
6	6	2.7 ± 3.1	0	0	0	0
16	3	3.3 ± 4.0	3.0 ± 2.6	9.0 ± 5.2	0	3.7 ± 3.2
28	3	3.0 ± 4.4	20.0 ± 0.0	12.0 ± 0.0	3.0 ± 3.0	20.0 ± 0.0
Group 4: Progesterone and FSH						
4	6	3.0 ± 3.0	0	0	0	0
6	6	2.8 ± 2.7	0	0	0	0
16	3	6.7 ± 3.2	2.0 ± 2.0	12.0 ± 0.0	0	2.7 ± 2.3
28	3	7.0 ± 4.4	20.0 ± 0.0	12.0 ± 0.0	3.3 ± 2.5	20.0 ± 0.0
Group 5: Control						
4	6	4.8 ± 2.6	0	0	0.2 ± 0.4	0
6	6	5.8 ± 2.6	0	0	0.2 ± 0.4	0
16	6	6.2 ± 3.0	3.5 ± 2.2	12.0 ± 0.0	0.2 ± 0.4	2.8 ± 3.1
28	5	6.2 ± 3.6	20.0 ± 0.0	12.0 ± 0.0	0.2 ± 3.0	20.0 ± 0.0

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[a] Flock 2 was 3 months old at beginning of study. Feathers replaced at time of inspection.

[b] Primaries on right wing removed 7 days after start of study.

[c] Mortality greater than anticipated due to an extraintestinal coccidial infection.

[d] Replacement primaries deformed, lost repeatedly throughout study.

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HERPESVIRUS IN CRANES: A NEW DISEASE

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Abstract: Three mysterious epizootics occurred in geographically separated captive crane flocks in the period 1973-79. The cause of death of the 46 affected cranes, in Austria and the United States, appears to be a herpesvirus and the disease has been named Inclusion Body Disease of Cranes. Six crane species were involved in the deaths and six other species were exposed but all individuals survived. Future infection of crane flocks by a virulent virus or other etiological agent could produce sudden and devastating losses within the world's endangered crane populations.

Seven of the 15 species of cranes in the world are presently endangered due to loss of habitat, overhunting, and warfare. In an effort to save cranes from extinction, conservationists have established several facilities for captive breeding of cranes. The organizations operating these facilities are dedicated to establishing breeding stocks of cranes, gathering information about crane biology and ecology, and protecting habitat. Little is known about diseases of cranes; a circumstance recently regretted by crane enthusiasts when an unexplainable lethal virus suddenly appeared in captive flocks. As a consequence of 3 mysterious epizootics in geographically separated captive crane flocks, more disease research is presently underway.

The 1st such disease outbreak occurred in Safari Park of Vienna, Austria, in the winter of 1973-74. Nineteen cranes suddenly died within 15 days. In March and April of 1978, 22 of 50 non-breeding cranes died at the International Crane Foundation (ICF) in Baraboo, Wisconsin. The 3rd die-off happened at a private aviary in Rhode Island, in September of 1979, where 5 of 10 cranes were lost within a week. There have been no further epidemics, but occasional mysterious deaths in captive crane flocks add to concern that a pathogenic agent may still be active. In all epidemics mentioned, the cause of death appears to be a previously unknown virus. After histopathology of the birds infected at ICF and Vienna, a new herpesvirus was isolated which is currently being investigated.

The establishment of crane breeding facilities has required importation and exportation of all crane species to various locations around the world. Therefore, we need to know the answers to questions such as: Where does the herpesvirus come from? Was each outbreak caused by the same virus? What is the mode of transmission? Does transovarial transmission of the virus occur? Does it persist in a dormant state ready to appear again in the future? How does the pathogen compare to other avian herpesviruses?

This paper describes circumstances surrounding the 3 epizootics, and reviews research that is being conducted to understand pathogenesis of the new herpesvirus.

THE EPIZOOTICS

While George Archibald, ICF director and cofounder, was making a routine inspection of ICF, a young Stanley Crane (*Anthropoides paradisea*) walked up to him, shuddered, fell to the ground, and died. Shortly thereafter, more birds were found dead. These deaths occurred too close together to be mere happenstance, and suggested the possibility of an infectious agent. Careful observation was started on all birds and those appearing the least bit abnormal were hospitalized, given medication, and force-fed, but to no avail.

This dramatic experience indicates that advance warning of the virus is practically nonexistent. Clinically a crane 1st appears normal, 2 days later becomes lethargic, anorexic, and soon dies. The ICF cranes that died were kept in a large area of open field and woodland, making it impossible to identify an intruder that might have carried in the virus.

When ICF's outbreak was compared to that in Vienna, I found that the caretakers in Vienna reported behavior by sick cranes which was similar to that observed at ICF: separation from the flock, inactivity, inappetence, and diarrhea, followed by death within 2 days. The Vienna flock had been housed in heated buildings due to cold weather.

In the Rhode Island aviary, the birds were housed in separate areas and showed signs of lethargy and anorexia. It should be noted that cranes at ICF and Rhode Island were housed outdoors so that mechanical means of transmission could have introduced and spread the virus. A mouse, rat, or bird could have carried the disease agent on its body in feces, mucous, or a similar excretion.

The outbreak at ICF necessitated involvement of the National Wildlife Health Laboratory (NWHL) of the United States Fish and Wildlife Service. Virologists isolated a viral agent from pooled livers and spleens taken from the deceased birds, then tentatively named the pathogen Inclusion Body Disease of Cranes (IBDC)(Docherty and Henning 1980). The IBDC pathogen was identified as a herpesvirus on the basis of its ability to form intranuclear inclusion bodies, ether sensitivity, nucleic acid type, and cytopathic effect on embryo fibroblasts of 15-day-old Pekin ducks and 10-day-old white leghorns.

The number of crane species affected by the virus was greater at ICF than in Vienna or Rhode Island. The infected crane species that died were red-crowned (*Grus japonensis*), hooded (*G. monachus*), sandhill (*G. canadensis*), and Stanley. Cranes that tested positive for antibodies after the outbreak include the common (*G. grus*), sarus (*G. antigone*), East and West African crowned (*Balearica regulorum* and *B. pavonina*), demoiselle (*Anthropoides virgo*), white-naped (*G. vipio*), hooded, sandhill, and red-crowned. The Vienna Safari Park only exhibited 2 species, the demoiselle and East African crowned cranes, and all of these cranes subsequently died. Similar circumstances existed at Rhode Island where only demoiselle and East African crowned cranes were housed; half of the flock died.

These findings generate several observations and questions. First, 14 species were exposed to the virus at ICF. Why did all the species of cranes at ICF not succumb to the disease? Is the virus more pathogenic to certain species? Only 4 species housed at ICF died during the outbreak, so it appears that species immunity is a very likely possibility.

Another aspect is the closeness of housing in relation to die-offs. The birds at ICF are kept in 4 different areas; the outbreak occurred in the nonbreeder area although cranes in the 3 breeding units were also affected to a lesser degree. Neutralizing antibody was found in cranes from all 4 areas. The deaths in Rhode Island cranes also occurred in separate areas of the aviary, which leads an observer to believe the virus is highly transmissible.

Demoiselle cranes died in Vienna but not at ICF, although at ICF they produced antibodies to the virus. Could the cranes have been exposed to different strains of virus or was the body chemistry of the deceased birds simply less resistant? Perhaps a comparison of necropsy reports will help clarify the character of the virus or viruses involved.

The pathomorphological characteristics of the disease were established primarily through study of the liver, spleen, and kidney. Necropsy reports on the cranes in Vienna indicated the livers were slightly to moderately swollen and friable. Numerous grayish-yellow necrotic foci were detected. The kidney and spleen were swollen and contained necrotic foci. Focal necrosis was also present in the digestive tract, bone marrow, and thyroid, but the most significant findings were histological. Inclusion bodies of type A as described by E. V. Cowdry were found near the necrotic foci. Electromicroscopically the virus could be identified as a Herpes virus (Burtscher and Grunbery 1979).

ICF necropsy reports were similar; affected tissue contained inclusion bodies, and the liver, spleen, and kidney were very friable. Unfortunately, postmortem changes and freezing of the Rhode Island cranes prevented complete necropsy, and inflamation of the intestinal tract was the only lesion detected. As a result, histopathology to look for intranuclear inclusion bodies could not be adequately performed. The structure of the virus seems to be the same in at least 2 of the outbreaks, but nothing has been definitely proven. Morphological similarities of IBDC also exist with herpesvirus infections in cormorants, owls, falcons, pigeons, storks, and Patcheco's Parrot Disease (Burtscher and Grunberg 1979).

CHARACTER OF HERPESVIRUSES

The herpesvirus structure is that of a nucleic acid enclosed in a shell of protein. The protein, or capsid, is capable of determining the susceptible hosts of the virus by binding with specific host-cell receptor sites. Herpesviruses are adapted to particular cells and, therefore, require a long period for growth and duplication. Transmission is usually by direct contact with the source, i.e., secretions from the respiratory tract, lesions, and excretory system.

Types of cell destruction or cytopathogenic effect (CPE) are often characteristic of certain kinds of herpesviruses. Three common features of cells infected by most of the types of herpesviruses are convolution of the nuclear membrane; viral envelope acquisition obtained by budding from cellular membranes, usually from the inner nuclear membrane; and inhibition of cell-specific protein synthesis. A virus infection gradually phases out the cell's production of its own proteins and induces virus-specific protein synthesis. Productive infections invariably lead to cell death (Kaplan 1973).

Intranuclear inclusion bodies are characteristic cellular lesions that form as a result of herpesvirus infection. There are types A and B cellular lesions. Type A inclusions, which may be related to a crane herpesvirus (Burtscher and Grunberg 1979), are single homogenous pleomorphic bodies occupying the central portion of the nucleus and eventually causing cell destruction. Nuclear alterations are the result of an infection of any of the herpesviruses.

Use of the electron microscope has revealed many alterations induced by interactions between viruses and cells. One aspect characteristic of herpesviruses is that the infected cells tend to fuse or clump. Polykaryocytosis, the formation of multinucleated cells called polykaryocytes or syncytia, is a quite prevalent result of herpesvirus infections (Kaplan 1973). Polykaryocytosis may occur early or late after infection, depending on the period of maximum virus replication with which it coincides. The degree of polykaryocyte formation depends mostly on the genetic makeup of the virus, but may be partially affected by the host cell.

Herpesviruses seem to be ubiquitous. When an infection occurs the virus probably remains with the host for life in a latent form. Infections can be reactivated by nonspecific stimuli years after the initial infection. Herpesviruses may produce little or no illness in their specific host species but give rise to a commonly fatal disease if they cross host species barriers (Kaplan 1973). In its latent form, infectious virus cannot be detected or recovered, and is not produced. Environmental stimuli, however, are capable of inducing both production and shedding of the virus. Such virus production may soon be followed by clinical illness and these relapses may occur repeatedly. Intermittent shedding of virus is a recognized phenomenon of herpesviruses.

Mutations occur readily in a virus. There are many differences in subgroups of herpesviruses, even within a particular strain. Subgroups differ in properties such as virulence, cytopathology, ability to alter cell membranes, host range, altered physical and chemical properties, altered plaque types, and intracellular development (Kaplan 1973). It is not easy to work with a herpesvirus because usually the researcher deals with very small amounts of isolated virus. After repeated passages in tissue culture, while attempting to strengthen the isolate, the researcher also risks the chance of forming virus mutants.

CURRENT RESEARCH

Research continues despite difficulties of dealing with herpesviruses. Once researchers thought duck plague (DP, duck virus enteritis) virus, also a herpesvirus, and IBDC virus were similar. In the past decade, there have been a series of seemingly unrelated outbreaks of DP in captive waterfowl (Burgess et al. 1979). Duck plague now appears to be distinct from IBDC because DP virus antisera does not cross-neutralize (Docherty and Henning 1980). DP virus still poses problems in the study of IBDC virus because tissue culture (in muscovy, mallard [*Anas platyrhynchos*] or pekin duck cells), that is needed to grow large quantities of high titered virus, may be already infected with DP. Fortunately, it is possible to separate the 2 if they are accidentally present in the same culture.

The NWHL virologists investigated 95 live-trapped sandhill cranes from Wisconsin and Indiana in 1976 and 1977 to check for IBDC in wild populations (Docherty and Henning 1980). None of the crane sera had neutralizing antibodies to IBDC virus, thus suggesting that crane herpesvirus is nonexistent in this particular flock of sandhills. However, more testing would better support this assumption. NWHL virologists also showed that adult American coots (*Fulica americana*) and white pekin ducklings up to 17 days old are susceptible to IBDC virus after inoculation, and that 64-day-old muscovy ducks and 16-day-old white leghorn chicks are not susceptible. Among the ducklings exposed to IBDC virus, 1 of 4 inoculated intraperitoneally died, whereas all 4 inoculated intramuscularly (IM) died. Congested livers, spleens, and kidneys were characteristic of all birds that died.

From those cranes that were in the approximate vicinity of the ICF outbreak, blood and cloacal swab samples were taken repeatedly for 12 months by NWHL personnel. Neutralizing antibodies to the virus were found in many of the cranes. Some of the titers remained constant and some decreased, but others fluctuated. Reasons for this variation have not yet been determined. Cranes housed at an assumed safe distance from the outbreak were later discovered to have antibodies present in their system. These cranes were never exposed to the cranes which died or had shown antibodies, and they had previously tested negative for herpesvirus or its antibody. It is unclear why they exhibited antibodies later.

To further study the ICF IBDC virus, the Veterinary Science Department at the University of Wisconsin-Madison has undertaken a project to develop a sensitive diagnostic test. By experimentation with captive cranes previously exposed to the virus at ICF, and with those which were not exposed, they hope to develop the ELISA test (Enzyme-Linked Immunosorbant Assay) to determine if these birds are now carriers and shedders of the virus, and learn how the virus exists in its latent state. It would then be possible and advantageous to monitor cranes for IBDC in the wild and in other captive situations.

The ELISA test was chosen for its highly sensitive measurements of antigen and antibody levels. Use of antibodies labeled with an enzyme for high sensitivity of immunologic tests has only recently been developed (Enzyme-Immunoassay, EIA), but has been found fairly successful in its specificity, cost-effectiveness, and time element. Its development will hopefully equal or exceed such test systems as serum neutralization, immunofluorescence, and radioimmunoassay. The most frequent and substantial application of ELISA involves antibody:antigen measurements, although measurements also include haptens, macromolecular hormones, bacterial toxins, and steroids.

Besides serum assays, EIA has been applied to cerebrospinal fluid, urine, and milk (Wisdom 1976). The use of ELISA in virology was 1st reported for its detection and measurement of rubella antibody. It was again efficient and reliable in the assay of antibody to herpes simplex virus. Frequently it is used for detection of viruses in trees and plants, and is advantageous for detection of minute amounts of snake venom and its antibody. EIA tests have also been applied to hog cholera, trichinosis, and bovine brucellosis (Saunders et al. 1977). Hence, EIA has proven valuable for detecting antibodies to viral, parasitic, and bacterial disease elements.

The 1st step in developing the diagnostic test required isolation of the virus from infected animals to use as stock virus. This was done by the NWHL personnel. Presently Dr. JoAnn Schuh, investigator at the Veterinary Science Department, is using this stock to grow large quantities of high titered virus in tissue culture. Highly purified preparations of virus are essential for successful use of ELISA. The method used for obtaining these preparations will most likely be ultracentrifugation, although methods of ultrafiltration may also be tested. Other problems dealt with are finding a steady supply of cells which are sensitive enough to cause good plaqueing, and ascertaining that the cells are not already infected with duck plague.

When applied to IBDC virus, ELISA may be used to detect both antigen and antibody levels. The indirect ELISA procedure tests for antibody in a specimen, whereas the Double Antibody Sandwich Method indicates the amount of antigen present. The latter method will be adapted to IBDC 1st, and proceeds as follows. Specific antibody will be used to coat test tubes by passive adsorption. After any excess is washed away, the substance to be tested is added, and any antigen that is present will bind to the antibody. A 2nd washing will remove the substance if antigen is not present. The next step requires use of an enzyme-labeled specific antibody to bind to the 2nd site on the antigen. This antibody is prepared by injecting purified virus inoculate into lab animals other than cranes to obtain antiserum.

Through dialysis, the immunoglobulins are purified from the serum, and then labeled with an enzyme. After another wash, an enzyme chromogenic substrate is added which contains a color property that the enzyme-labeled specific antibody will bring out by freeing itself from the antigen and attacking the substrate. The intensity of the liberated chromogen is directly proportional to the amount of antigen present in the test specimen. If color is absent, it is presumed that the enzyme-labeled specific antibody found no antigen with which to bind itself and, thus, washed away.

During the process of developing ELISA, cranes at ICF that were previously exposed to IBDC are being cloacally swabbed monthly to detect any shedding of virus. Swabs are taken weekly throughout the breeding season because it is possible that stress at this time may induce shedding of virus. There has been a limited supply of cells on which to cultivate virus and, because ELISA is at an infant stage, most of the swabs are now frozen in fetal bovine serum. Crane herpesvirus is cultivated primarily in embryonated eggs and in tissue culture cell suspensions in flasks or in monolayers on glass surfaces, but when individual cranes are available the virus is extracted from infected tissue.

At ICF's annual health check, all cranes are swabbed and blood is taken to determine presence of virus and antibody to IBDC. Until ELISA can be adapted, the methods used for diagnosis are virus and serum neutralization tests. These tests are based on the fact that noticeable activity of the virus, whether it be CPE in cell culture, lesions, or death in embryonated eggs or animals, can be inhibited by specific antibody serum to that virus. For example, to identify virus using virus neutralization, an equal amount of virus plus several serums containing specific antibodies to different viruses are mixed separately and incubated. A host system is inoculated with this mixture, incubated, and observed for signs of CPE. If there is a mixture where cytopathic changes do not occur, it is assumed that the virus is neutralized and the isolate can be identified by that particular serum. Unfortunately, a crane might harbor a very low level of herpesvirus that this test is not sensitive enough to determine. The lack of test sensitivity affirms the need for a reliable diagnostic method.

By studying offspring of cranes exposed to IBDC it may be possible to discover whether transovarial transmission of the virus occurs. In a recent study, a 7-month-old common crane, hatched from a female that tested positive for IBDC antibody, was kept in isolation to observe possible shedding of the herpesvirus. After repeated bleedings and swabbings that tested negative for antibody and virus isolates, the chick was given Cyclophosphamide, an immunosuppressive agent, to attempt to induce shedding if it was harboring very low levels of virus. Evidence of virus was still not apparent so the chick was exposed to a passage of the stock virus.

Approximately 0.3 ml of virus was incoulated IM in the breast. Waterfowl are most susceptible to fatal infections via the IM route (Spieker 1978). Close observation showed a decrease in the chick's appetite and an increase in listlessness. By the 4th day, green feces were apparent, indicative of excess bile from liver nonfunction. After 7.5 days, the chick died. A necropsy revealed diffuse multifocal necrosis, congestion, and enlargement of the liver. The spleen was enlarged and the gastrointestinal tract full of bile. There was not enough time for the chick to develop antibodies; however, a liver suspension did cause typical herpesvirus CPE. Tissue was frozen for a future attempt to find evidence of crane herpesvirus and subsequently reisolate it from fresh tissue.

In future experiments with cranes, modes of transmission and virulence will also be investigated. Aerosols and drinking water are possible ways for exposing different cranes to the herpesvirus.

LONG-RANGE EFFECTS

Currently, combat against crane herpesvirus appears to be well under way at ICF. Prevention rather than control of the virus receives daily attention because all captive cranes appear healthy. Maintaining a sanitary environment (i.e., daily cleaning of shelters, caretaker use of foot baths, and other techniques), providing fresh feed and water, adequate individual bird space, daily observations, and annual health checks all contribute to successful crane management. As an added precaution, any bird possibly exposed during the 1978 outbreak is housed in an area separate from breeding facilities. Noone can approach the vicinity of the unexposed cranes without 1st showering and changing clothes. New crane arrivals also will be placed in quarantine for 2 weeks before being housed on the new ICF property not previously exposed to IBDC.

In terms of conservation, it is important to consider the future survival of wild crane populations. Unchanged since the Eocene, 1 or many crane species might be eliminated by an epizootic in the wild. Interference and development of natural areas by man has been creating adverse conditions for a bird that remains particular about its habitat. Lesser and Canadian sandhill cranes (*G. c. canadensis* and *G. c. rowani*) annually migrate north from Texas and Mexico to their staging grounds on sandbars of the Platte River in Nebraska. Over the past century the Platte's flow has rapidly diminished due to diversion for irrigation, for cooling power plants, and upstream impoundments.

For protection, the cranes will roost only on open sandbars in broad channels of shallow water, with access to nearby wet meadows and cornfields where they feed. These requirements limit the roosting grounds to only about 125 km of the total river distance between Grand Island and Sutherland, Nebraska. Fortunately, Nature Conservancy and the Platte River Whooping Crane Critical Habitat Maintenance Trust are combining efforts to preserve the area's migratory bird habitat. For 6 weeks from late February to early April, cranes are present to replenish their body's energy reserves and condition themselves for the journey northward to their breeding grounds. However, if a disease outbreak should occur at the staging grounds, we risk losing much of the world's lesser and Canadian sandhill crane populations.

Another area of concern exists because of an artificial feeding program in Arasaki, Japan (Nishida 1980). Over 4,000 hooded and white-naped cranes gather at a feeding station near their wintering grounds, where crane feed is plentifully provided due to a government subsidy. This high concentration of cranes probably irritates farmers who experience excessive crop damage, and could possibly disturb natural instincts to find other adequate feeding territories (Nishida 1980). More importantly, the high density of cranes could lead to rapid communication of disease such as deadly herpesvirus. If the artificial feeding program is phased out, and the Arasaki roost site protected, the overcrowded situation might be alleviated.

CONCLUSION

Three serious epizootics have recently occurred within captive crane flocks. Future infection of crane flocks by a virulent virus or other etiological agent could produce sudden and devastating losses within the world's endangered crane population; consequently, it is essential that measures of control and prevention be immediately undertaken. It is necessary to protect captive crane flocks from infectious agents by maintaining a sanitary environment, and by keeping healthy birds away from known diseased flocks. Crane conservationists need to keep a close watch on roosts and on staging and wintering grounds of wild populations because overcrowded conditions could precipitate a disease outbreak. Through continued epidemiological studies, identification and an understanding of past epidemics will aid in management and propagation techniques for many years to come.

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REFINED TECHNIQUES IN CRANE PROPAGATION AT THE INTERNATIONAL CRANE FOUNDATION

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Abstract: This paper describes refined techniques used to propagate cranes at the International Crane Foundation. An experiment with diets of different protein levels is outlined and preliminary data are given. Ideas are presented for safer and easier artificial insemination. Experiments are described that yielded a higher hatch rate among artificially incubated eggs. Finally, an experiment is presented that may produce hand-raised birds suitable for release into the wild.

INTRODUCTION

Captive propagation is currently regarded by some as a useful tool in safeguarding the short-term survival of some endangered cranes. The use of captive-produced eggs and birds for restocking purposes is currently under way with whooping cranes (*Grus americana*) and Mississippi sandhill cranes (*G. canadensis pulla*)(Drewien and Bizeau 1978, Derrickson 1981). The quantity and quality of birds and eggs available for these and future restocking efforts depends on sound propagation programs.

The number of institutions keeping and successfully breeding cranes in captivity has increased in recent years. The number of reports on the captive management of cranes has increased concurrently with the number of breeding centers for these birds (e.g., Griswold 1962, Archibald 1974, Erickson 1975, Sauey and Brownsmith 1977, Archibald and Viess 1979, LaRue 1981).

This paper will report on refined propagation methods and ongoing avicultural research at the International Crane Foundation (ICF). Particular attention will be given to diet, artificial insemination, artificial incubation, and chick rearing.

I thank those people at ICF who contributed to this year's breeding success: Dr. G. Archibald, B. Baechler, C. Baumann, R. Besser, L. Fields, C. Jeffers, S. Rogers, and S. Russman. My gratitude is expressed to the University of Wisconsin-Madison Poultry Science Department; especially to Dr. M. Sunde who formulated the diets used at ICF; to Dr. B. C. Wentworth for his suggestions and help with the artificial insemination program; and to Dr. J. Skinner for his help on incubator hygiene. Special thanks goes to S. Russman whose advice and knowledge has been incorporated into the section on artificial insemination.

DIET

Adult cranes at ICF receive a breeder diet containing 20.5% protein beginning 1 month before breeding, throughout the breeding season, and until the molt is completed. A maintenance diet with 19.4% protein is fed the remainder of the year, constituting a 1.1% difference in protein levels between the 2 diets (LaRue 1980a, Russman and Putnam 1981).

Testing of another breeder diet was begun in 1981 using 4 pairs of Florida sandhill cranes (*G. c. pratensis*), 5 pairs of common cranes (*G. grus*), and 5 pairs of hooded cranes (*G. monacha*). Half of these pairs received a breeder diet containing a minimum of 22% protein. These same birds will receive an experimental maintenance diet containing 16.7% protein through the fall and winter. The resulting difference in protein levels for the experimental diets is at least 5.3% as opposed to the 1.1% protein difference in the previously described breeder and maintenance diets. As experimental controls, the remaining pairs are fed the usual diet.

The greater difference in protein levels of the experimental diets may more closely resemble seasonal variations in diets of wild cranes. Walkinshaw (1949) reports sandhill cranes eat more vegetable matter, especially grains, during the winter than during the summer. Similarly, the critically endangered Siberian crane (*G. leucogeranus*) feeds almost exclusively on sedge tubers on its wintering grounds (Sauey 1976), but eats considerably more animal matter while on its breeding grounds (Spitzer 1979). Conversely, the whooping crane seems largely dependent on animal matter throughout the year (Allen 1952).

The success or failure of these experimental diets will be examined by comparing the breeding success, as measured by egg production, of both groups. Suitability of the experimental breeder diet was tested beginning in 1981. Only the 22% protein diet has been used throughout 1 season. Cranes have only recently been started on the 16.7% protein diet. Whatever effect the greater protein difference will have on breeding onset and success cannot be examined until at least the completion of the 1982 breeding season. Increased sample size, including additional species, is

Table 1. Egg production of birds on experimental diets.

		Number of eggs		
			1981	
Species	Pairs	1980	20.5% protein	22% protein
Sandhill	Topo/Gigio[a]	2		1
	Ernie/Bert[b]	0		4
	JC/Terry[c]		2[d]	
	Oscar/Pasque[c]		5	
Common	Bill/Helga	0		0
	Thor/Mrs. Thor	0		0
	Inga/Mrs. Inga	2[d]	8	4
	Olaf/Mrs. Olaf	2[d]	0	
	Nils/Mrs. Nils	0	0	
Hooded	All pairs	0	0	0

[a] At Patuxent Wildlife Research Center; bred 1972-1980. Yearly egg production $\bar{x}$ = 5; range = 1 - 10.

[b] At PWRC 1978-1980; did not breed.

[c] At National Zoological Park's Conservation and Research Center 1974/75-1980; past breeding performance unknown.

[d] Allowed to incubate their 1st clutch.

desirable for future trials. This year's results are presented in Table 1. The only conclusion that can be drawn so far is that the birds will produce eggs on either breeder diet.

ARTIFICIAL INSEMINATION

The basic procedures for artificial insemination (AI) of cranes have been given by Archibald (1974), Gee and Temple (1978), and LaRue (1980b). However, I would like to expand on these reports with details that may make the AI of cranes safer, easier, and hopefully more productive.

Protective Equipment and Hygiene

Protective equipment and clothing are an essential part of the AI program at ICF including reinforced coveralls and safety goggles. Only 1 minor eye injury has occurred to an ICF employee while the birds were being handled for AI. However, the great frequency with which the birds are handled during the breeding season makes the occurrence of a major injury very probable. Consequently, safety goggles are worn by members of the AI team as a precaution against injury from a bird's bill, wings, and feet.

Coveralls are also worn by all aviculturists during AI. These coveralls have a durable synthetic fabric sewn to the fronts of the legs from the pant cuff to the mid-thigh. This fabric protects AI personnel from injury which can result from a bird's claws when it struggles, and protects personal clothing. It is advisable to encircle the entire leg with heavy fabric because many rips occur on the back of the pant leg. These coveralls are worn only during AI and serve as a constant image for the birds which aids in conditioning them to the AI routine.

During AI, aviculturists wash their hands with an iodine solution and towel dry them after each pair is handled or when going from pen to pen. This cleansing reduces the risk of disease transmission during the frequent handling of the birds. Boot wash pans are available at the entrance of all pens and each person dips their shoes when they enter or leave.

Shot glasses for semen collection are cleaned after each use. They are washed in hot soapy water, rinsed with hot water, and steamed about 30 minutes at 90° C. The glasses are then stored in an inverted position on clean paper toweling. This washing procedure removes contaminants which could be detrimental to sperm collected the next time.

Insemination of the Female

When a female crane comes into breeding condition her cloacal lips will swell and redden. Laying of the 1st egg is sometimes preceded several days by the appearance of a blood spot at the terminus of the oviduct. After a female has begun egg production it is advisable to palpate her abdomen for the presence of an egg before collecting semen from the male. An egg can be felt in a female's oviduct as much as 48 hours before oviposition.

Although uterovaginal sperm host glands occur in the domestic chicken and turkey (Lake 1975), semen storage capabilities have not been conclusively proven in cranes. Circumstantial evidence for semen storage in cranes has been observed at ICF. In 1981, a pinioned pair of Stanley cranes (*Anthropoides paradisea*) were being artificially inseminated until it became impossible to obtain semen samples. It appears our inability to collect semen was due to the pair's attempts at copulation. An experienced observer was in a blind next to the pair's pen at most times during which unsuccessful copulation attempts were observed. Seven and 10 days after the last successful insemination the female laid 2 fertile eggs. No AI was performed afterward and more unsuccessful copulation attempts were observed. The next 2 eggs, laid 14 and 18 days after the 1st clutch, were infertile. Thus it appears that some females may store semen for up to 10 days and produce fertile eggs.

Postoviposition inseminations provide the highest probability of fertilizing the next egg. It is best to collect semen from the male after the female has laid the egg already in her oviduct because, if semen is collected in the morning and an egg is laid that afternoon, it is very difficult to obtain a 2nd semen sample that day. Do not fail to inseminate after the 2nd egg in a clutch because 3-egg clutches do occur. For multiple clutches, continue inseminating until the female stops laying.

If semen is collected and an egg is discovered when attempting to inseminate the females, it is possible to save that semen for later insemination. Gee and Temple (1978) report that semen stored at 4-10° C will retain motility for at least 8 hours. Semen stored in 1.00 ml tuberculin syringes at 7-9° C at ICF have retained motility for up to 32 hours (S. Russman, pers. comm.). However, variations in storage time and sperm survivability appear to be characteristic of individual males, and inseminations with fresh semen are preferable.

During AI, the most difficult part of the operation can be inseminating directly into the female's oviduct. In past years, the oviduct was located by having 1 member of the AI team separate the cloacal lips with both index fingers (LaRue 1980b). However, this technique is difficult for large-fingered persons, and some female cranes will struggle when handled in this fashion, thus making proper insemination even more difficult.

Another technique was tried in 1981 which proved successful with most females in full breeding condition. These females will evert their cloacas while being stroked on their backs and sides. It is then possible to bring the terminus of the oviduct into view at the cloacal opening by placing the fingers of the left hand on the bird's rump while firmly pressing upward with the thumb between, and slightly anterior to, the tips of the pubic bones. A syringe can then easily be inserted with the right hand. The oviduct can be distinguished from the surrounding tissue by its redder color and spongy texture. This method has been successfully employed on red-crowned (*G. japonensis*), white white-naped (*G. vipio*), sarus (*G. antigone*), Siberian, and sandhill cranes.

Record Keeping

Complete records are maintained on each bird's breeding performance. A field notebook is maintained throughout the breeding season in which each bird's performance during AI is logged. The following information is recorded for each male: date, time, weather conditions, response, semen volume, extension (dilution) of the semen, and its quality. Similar information is collected for each female: date, time, weather conditions, response, volume of semen inseminated, extension of semen, semen quality, and pelvic spread. Additional comments are recorded on the presence of contaminants in the semen, presence of an egg in the female's oviduct, presence of a blood spot, and any injuries a bird may have sustained during AI.

This information is transferred to a permanent yearly record. For females, this record includes the dates of egg-laying and fertility. See Fig. 1 for examples of field and yearly rec-

Date	Name	Response	Volume (ml)	Extended	Quality	Comments
14 May Sunny	Butch	+++	0.03	1:2	A/90	
75° F	Bette	+++	0.03	1:2	A/90	2 fingers

Permanent notebook

Example for male: Butch

Date	Response	Volume (ml)	Quality	Comments (weather etc.)	Female insem.	Volume insem.
14 May	+++	0.03	A/90	sun, 75° F ex 1:2	Bette	0.03
17 May	+++	0.10	A/70	rain, 65° F	Bette	0.10

Example for female: Bette

Date	Response	Volume (ml)	Comments (Grade, extension)	Fingers	Egg no.	Egg date	Fertility
14 May	+++	0.03	A/90 ex 1:2	2			
16 May			Felt egg	2			
17 May	+++	0.10	A/70	2	3	17 May	F

Fig. 1. Excerpt from AI field notebook.

ords. These yearly data are summarized and recorded on each bird's lifetime record, which provides an overview of the bird's total breeding performance.

A bird's response, rated - to +++, has been described in LaRue (1980b). A female's pelvic spread is measured in widths of a man's finger. The pelvic spread of some females increases during the breeding season from 1 finger (about 20 mm) to as much as 4 fingers (about 70 mm); pelvic spread of other females remains fairly constant.

Semen volume is measured in 1.00 ml tuberculin syringes. Uncontaminated semen volumes range from 0.01 to 0.30 ml. The extension of semen is measured by the ratio of parts semen to parts diluent. Sperm quality is recorded as a 2-part grade, e.g., A/90. The letter grades A, B, C, D, and F reflect the concentration of sperm as viewed through a microscope at 400X (Fig. 2). The numerical grades represent the estimated motility from 0 to 90%. The staff arbitrarily decided that samples extended 1:10 or more be upgraded 1 letter grade and that no sample be given a rating of over 90%. An attempt is being made to correlate each letter grade with a range of actual concentrations (spermatozoa/ml) with use of an hemacytometer. This grading may eventually shed light on the concentration of spermatozoa needed to fertilize a crane egg.

An analysis of 5 years of semen data, 1976-1980, has produced some interesting results (C. Baumann, unpubl. ICF rep.). Baumann found that the period of semen production ranged from 67 to 103 days. Peak performance, as measured by high quality "A" samples, ranged from 46 to 82 days. He also noted that some male's semen production, as measured by the percentage of "A" samples, improved over the years. This improvement is probably due to their growing accustomed to the frequent handling involved with AI. Baumann also found that the average volume of semen per ejaculate of some males decreased each year. This trend probably reflects a decrease in the amounts of contaminants in an ejaculate.

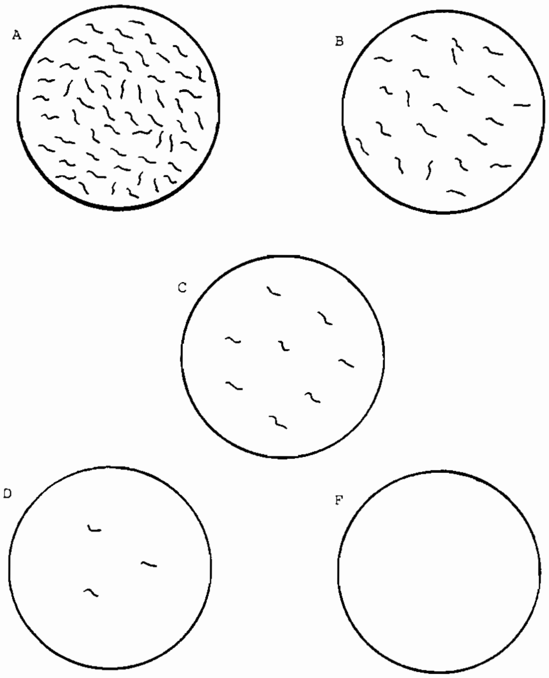

Fig. 2. Letter-graded semen samples. A, very dense concentration of sperm; B, a few spaces appear between sperm; C, isolated sperm throughout the field; D, very few sperm; F, no sperm.

ARTIFICIAL INCUBATION

Eggs are collected for artificial incubation soon after they are laid. An egg is picked up with a plastic glove, placed in a protective box, and transported to the incubator room. Plastic gloves are worn to avoid contamination and the egg is not directly touched until just before hatching. The egg is cleaned by placing it in a commercial quarternary ammonia egg-wash for several minutes. Keeping the cleaning solution the same temperature as the unset egg minimizes the flow of water into the egg. Any blood, dirt, or grass stains are removed by gentle rubbing.

As soon as the egg dries, it is weighed and maximum length and width measured. This information along with date, egg number, and parent names, are recorded on an egg data sheet (Fig. 3). A 6-digit egg number, for example 08-06-04, is penciled on the pointed end of the egg. These numbers respectively represent the species number, individual female's number, and the position of that egg in the seasonal number of eggs laid by the female.

Proper embryonic development depends on certain physical optima, namely gaseous factors, temperature, and egg position (Drent 1975). The successful hatching of artificially incubated eggs has been the weakest point in the propagation program at ICF and especially in recent years (Table 2). For the results of earlier years see Archibald and Viess (1979). New techniques were tried in 1981 in an attempt to improve hatchability. But before outlining these methods, it is 1st necessary to describe the problems encountered.

At ICF, embryonic death most often occurs during the last several days of incubation. Romanoff (1972) has shown similar peaks in mortality for chicken and turkey eggs. The crane embryos were often active up to and partially through the hatching period, but then would weaken and die. The chicks had usually failed to tear the inner shell membrane. This membrane often still contained blood in its vessels, a situation abnormal for usual hatching. The embryos were sometimes malpositioned but often not.

Table 2. Hatching success at ICF 1979-1981.

Year	Conditions	% hatchability	Sample	% vitality	Sample
1979	Artificially incubated	50	22	NA[a]	NA
1980	Artificially incubated	45	20	30	20
1981	Naturally incubated > 20 days	80	5	60	5
	Started under sandhills < 7 days then artificially incubated	71	7	71	7
	Artificially incubated	77	31	55	31

[a] NA means not available.

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Succession No. ____________

Date ____________

Incubator No. ____________ F ________ I _____

Egg No. _______ Dam ________________ Sire ________________

Egg length ______mm Egg width _______mm Egg weight (initial) __________g

Egg weight (end) ____________g % weight loss __________

Day	Weight	Day	Weight
1		19	
2		20	
3		21	
4		22	
5		23	
6		24	
7		25	
8		26	
9		27	
10		28	
11		29	
12		30	
13		31	
14		32	
15		33	
16		34	
17		35	
18		36	

Remarks ____

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Fig. 3. Egg data sheet.

Dead unhatched embryos were sent to the National Wildlife Health Laboratory in Madison, Wisconsin, for necropsy. Pathologists were seldom able to pinpoint the cause of death. Subcutaneous edema was a feature common to many of the dead embryos but this may be a normal condition. Some chicks lacked vigor and had to be helped with hatching. These chicks would probably have died without human assistance in hatching. During normal incubation a chick usually pips within 36 hours of the onset of scratching and hatches within 24 hours of pipping. These periods are allowed to elapse before an aviculturist assists the bird in hatching. A mild styptic agent (aluminum chloride 25% in 70% alcohol) is useful for stopping membrane hemorrhages while the chick is being helped to hatch. The ICF staff assumed that their techniques were the cause, and not some defect within the egg, for the poor hatching results. Consequently, the following methods were tried in 1981.

The eggs were incubated in Petersime Model 1 forced-air incubators at 37.6° C (99.75° F) with a wet bulb reading of 30.0° C (86.0° F). However, white-naped eggs incubated at these temperatures in past years failed to lose enough weight. Hence, they have been incubated at 37.5° C with a wet bulb temperature of 27.8° C (82.0° F) since 1979. In 1981, however, 2 white-naped eggs were successfully hatched after being incubated at the higher humidity, while 13 other eggs successfully hatched at the lower humidity.

Patten (1957) noted that the early phase of embryonic development, during which the various dermal layers are formed, is a critical time for successful development. To test this idea on crane eggs, we placed some eggs from red-crowned and white-naped cranes under incubating sandhills for the first 3 to 7 days and then artificially incubated them. Siberian eggs were left under sandhills for most of the incubation period and 2 white-naped eggs were incubated entirely by the parents.

R. Prange (pers. comm.) found that wild sandhill cranes make frequent nest exchanges the first 3 days of incubation and thereafter usually exchange twice daily. During these exchanges the eggs are exposed to cooler temperatures. It was hypothesized that this cooling may have been 1 missing factor necessary for successful hatching. Rol'nik (1955, 1970) has similarly suggested that periodic cooling will improve the hatchability of nondomestic and some domestic bird eggs. However, Landauer (1967) believes that cooling is unnecessary, at least for chicken eggs.

To simulate nest exchanges, our artificially incubated eggs were placed in a small refrigerator at 4.0° C for 10 minutes, 3 times daily (at 0800, 1200, and 1700 hours), for the first 3 days of incubation. Thereafter, the eggs were cooled twice daily (at 0800 and 1700 hours). The eggs were also cooled to room temperature (20° C), for up to 30 minutes, while they were being weighed.

The eggs are weighed every 2nd day to determine their weight loss. Ar and Rahn (1980) have shown that most bird eggs lose 15% of their initial weight during natural incubation. The weights are graphed and most of our eggs lose between 13 and 17% of their initial weight. It is possible to move an egg to a different incubator to correct improper weight loss.

Two days before the expected hatching, the egg is removed from the tray and rested in a hollowed piece of foam inside a cage in the bottom of the incubator. The egg is candled and the outline of the air cell is traced in pencil. The larger portion of the air cell should be at the top when the egg is set down. After the egg is pipped it is removed to the higher humidity hatcher which has temperatures of 37.2° C (99.0° F) and 33.9° C (93.0° F) wet bulb. Before 1981 the eggs were moved directly to the hatcher; that method is no longer used. Embryonic respiration takes place largely through the chorioallantois until the chick has externally pipped (Rahn et al. 1979). Romijn (1950) has shown that the chorioallantoic membrane has a decreasing permeability to oxygen when exposed to increasing humidity.

Incubator Hygiene

The ICF incubators and hatcher are fumigated at the beginning of each season (with 40 ml formaldehyde and 20 g potassium permanganate per 100 ft^3). After eggs are put into the machines they are fumigated every 15 days. Fumigation of the hatcher is delayed if there are pipped eggs in it. It is important to closely follow the manufacturer's directions for fumigation because excessive amounts of formaldehyde are detrimental to the embryo (Romanoff 1972). The water pans for humidity are cleaned every 2nd day with a quarternary ammonia solution.

Sabarod and blood agar plates were exposed in the incubators and hatcher before and after fumigation. One hour was found to be the best exposure time. Also swabs should be taken of hard-to-clean spots and moist areas and then streaked on a set of plates.

Both times, a general atmospheric fungus, *Penicillium* sp., was isolated as were minor amounts of *Aspergillus* spp. Although it is probably impossible to eradicate these microbes, regular thorough cleanings should keep their numbers in check.

It may someday be necessary to place artificially incubated eggs in the nests of wild birds; therefore, it is important to examine hatchability and the vitality of the chick. I have calculated percent vitality, expressed as the number of eggs hatched without human assistance divided by the total number of fertile eggs, multiplied by 100. In comparing 1979-81 results, 1981 shows a large increase in hatchability (Table 2). The vitality of 1981 hatchings is also twice that of 1980 hatchings. When comparing different methods used in 1981, eggs completely artificially incubated have the same hatchability and vitality as naturally incubated eggs. Eggs started under sandhills and then artificially incubated have a lower hatchability but higher vitality than eggs in the other classes. Although the 1981 mortalities are fewer, they are of the same nature as those of previous years.

Although hatchability and vitality have been increased, the exact factors responsible for this increase cannot be precisely determined due to the many variables changed from 1980 to 1981. Further experimentation should lead to a better understanding of the optima required for successful incubation of crane eggs.

CHICK REARING

An experiment begun in 1981 may yield a method for hand-rearing cranes suitable for restocking. All successful attempts at releasing captive-raised whooping and Mississippi sandhill cranes have depended on birds raised by natural or foster parents. This dependence restricts the number of birds available for release attempts.

This year 2 Stanley crane chicks were hand-raised while visually isolated from people. Both chicks were raised in pens next to an adult pair of common cranes. Each chick pen has an outdoor run and an inside shelter. All sides of the pen are opaque except the side facing the common cranes. One pen has an indoor area of 3.0 m^2 and 11.1 m^2 outdoor. The other pen has 4.8 m^2 indoor and 12.9 m^2 outdoor and these are the preferred sizes. The floors are covered with sand. There is a sliding door between the indoor and outdoor areas that can be controlled from outside the pen. The chicks can be locked in or out so the pen can be cleaned without their being able to see people. The pens are also equipped with a regular mirror, a 2-way mirror for viewing the chicks, and heat lamps.

The chicks were taught to eat by a puppet modeled after the head of an adult Stanley crane. It has movable mandibles that work like scissors. The chicks learned to eat on their own when about 7-10 days old and thereafter required very little care. The isolated chicks were much quieter than chicks reared in contact with people. They made very few contact calls.

When the chicks were fully feathered they were exposed to people. The oldest chick fled from people and paced nervously if he could not get out of sight. The younger chick was not as skittish but still shunned humans. When handled, they both struggled more than hand-reared birds normally do. The younger chick in particular hissed and attempted to strike the handlers with her bill. The older bird died from stress while being laparoscoped, while normally hand-reared birds were examined without incident. The response of these chicks to wild predators has not been examined.

This technique may make it possible for large numbers of endangered cranes to be hand-reared for release without natural or foster parent rearing. This technique should also reduce the cost of rearing these birds because smaller pens are used, more chicks can be produced from each endangered pair, and large numbers of foster-parent pairs are not needed.

CONCLUSION

I have tried to accurately describe new methods tried at ICF in 1981, involving diets, artificial insemination, artificial incubation, and chick rearing, that may contribute to raising larger numbers of endangered cranes. Lack of firm and final results is a reflection of the immediacy and ongoing nature of this work. Larger samples and continued experimentation are obviously needed.

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FALL CENSUS OF EASTERN GREATER SANDHILL CRANES[1]

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Abstract: The eastern population of greater sandhill cranes (*Grus canadensis tabida*) breeds in the Lake States and southern Canada and winters from central Florida north to the Okefenokee Swamp in southern Georgia. The population was censused at known stopover areas throughout the migration path during fall 1979 and 1980. Cranes counted at the 2 principal staging areas, the Jasper-Pulaski Fish and Wildlife Area (JPFWA) in northwestern Indiana and the Haehnle Sanctuary in southern Michigan, accounted for about 81% of census totals. Apparently, little migration occurred past JPFWA and Haehnle before peak counts in late October. Census totals were 14,385 cranes in 1979 and 15,125 in 1980. The proportion of the population actually counted was unknown. Because of occasional years of abnormal turnover, and recent resumption of waterfowl hunting at JPFWA, future counts at JPFWA and Haehnle should not be considered reliable indicators of population trends without complementary counts throughout the migration corridor.

Reduced to a few dozen nesting pairs in Michigan and Wisconsin during the late 1800's and early 1900's (Henika 1936, Walkinshaw 1949:134), the eastern population of greater sandhill cranes has recovered dramatically in recent years. Reliable estimates of population size are needed for management purposes, but until now no census techniques have been devised or tested. The population is highly dispersed over its poorly defined breeding and wintering ranges. Census appears most feasible on concentration areas during migration. The primary staging site of migrant sandhill cranes wintering east of Texas is the Jasper-Pulaski Fish and Wildlife Area in northwestern Indiana where 13,000 cranes may be present simultaneously in fall. Cranes breeding in Lower Peninsula and eastern Upper Peninsula Michigan apparently stage primarily at the Michigan Audubon Society's Haehnle Sanctuary in southern Michigan, where peak fall counts currently are 700-1,300 cranes (H. F. Wing pers. comm.). Cranes stage earlier in the migration in concentrations of less than 1,000 at various areas throughout Wisconsin and Michigan (Taylor 1976, Hoffman 1977, Bennett 1978, Melvin 1978).

Attempts at simultaneous counts of sandhill cranes throughout the Central Flyway have not been successful. Although around 200,000 staging cranes were counted at the Platte River, Nebraska, each spring, Miller et al. (1972) noted 44% variation in annual census of a presumably stable population, and 35% difference between average annual census and estimated population size. Much discrepancy is caused by incomplete counts of all cranes along the Platte River and inadequate counts of migrants elsewhere in the Flyway from Canada to Mexico (Lewis 1979). Buller (1979) concluded that simultaneous fall counts throughout the Flyway were even less meaningful, owing to incomplete coverage of all concentration areas, inconsistency in counting techniques, and inability to predict a peak migration period as a necessary target for the massive organizational effort.

However, the migration corridor of the much smaller eastern population of sandhill cranes appears rather narrow, and significant stopover sites in fall are few and of limited area (Walkinshaw 1960, DeVore 1972, Melvin 1978, Patterson 1978, R. A. Crete and J. E. Toepfer 1978, unpubl. rep., U.S. Fish and Wildl. Serv., Twin Cities, Minn.; R. K. Anderson, D. K. Jansen, and T. Cogger 1980, unpubl. rep., U.S. Fish and Wildl. Serv., Twin Cities, Minn.). The purpose of this study was to assess feasibility of a simultaneous fall count of sandhill cranes throughout the eastern migration path, and the proportion of the population represented in weekly counts at JPFWA and the Haehnle Sanctuary.

Chronology of crane migration in the Lake States varies widely with weather and hunting regimes in particular areas. Cranes typically leave east-central Minnesota and upper peninsula Michigan by the end of September (Johnson 1976, Taylor 1976). Departure from nonrefuge areas throughout the Lake States usually occurs promptly with opening of waterfowl hunting season in early October, but

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until late November cranes remain on refuges as far north as Crex Meadows, Wisconsin (Walkinshaw and Hoffman 1974, Hoffman 1977, Bennett 1978, Melvin 1978, Anderson et al. 1980, unpubl., op. cit.).

Despite sundry concentration areas in the Lake States, none exist between the Lake States and Okefenokee Swamp in southern Georgia. Cranes are observed in flight and occasionally on the ground within a narrow migration corridor through eastern Tennessee and Georgia (DeVore 1972, Patterson 1978). Cranes commonly stop in the Tennessee Valley region near Hiwassee Island State Wildlife Refuge (DeVore 1972, Crete and Toepfer 1978, unpubl., Anderson et al. 1980, unpubl., op. cit., K. H. Dubke and W. K. James pers. comm.), but consistent concentration sites have not developed. Consequently, census dates should be late enough to ensure that cranes are concentrated and visible at northern staging areas, but early enough to avoid oversight of cranes having migrated south from JPFWA and the Haehnle Sanctuary.

Participants in the fall census were too numerous to list here, but I am particularly indebted to C. D. Besadny, L. Culp, G. Fannucchi, A. H. Grewe, R. A. Hunt, G. W. Irvine, M. Isham, W. K. James, J. N. Lane, R. McCracken, L. E. Nauman, R. G. Nord, S. A. Nesbitt, W. E. Taylor, H. F. Wing, and L. H. Walkinshaw.

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METHODS

Counts throughout the migration corridor were conducted in fall 1979 and 1980. Cooperators included personnel of state and federal natural areas, state wildlife researchers, university staff and students, private foundations, and experienced nonprofessionals. In 1979, cooperators were asked to make counts on or near 2 November, the expected date of peak count at JPFWA. Weekly counts during the migration were solicited where feasible. The target date was changed to 29 October in 1980, and additional counts 1 week before this date were obtained throughout Wisconsin. In 1980, surveys in Florida were delayed until 3 November to allow cranes in transit south of JPFWA on 29 October to arrive at wintering areas.

Enumeration methods included ground counts of cranes departing or arriving at roosts, feeding in fields, or in migration flights; aerial surveys of dispersed migration or wintering habitat; and counts from boats in the Okefenokee Swamp. At JPFWA, property staff stationed around night roosts counted cranes in the morning as they flew to feeding fields. At Haehnle, cranes were counted by Harold F. Wing, a local nonprofessional, as they arrived in the evening at a roost within the Sanctuary.

RESULTS

On the flyway-wide count on 2 November 1979, cranes were not observed in Minnesota or northern Michigan, but at least 1,370 were still present in Wisconsin and 750 in extreme southern Michigan (Table 1). Areas censused where cranes were not observed were Carlos Avery WMA, eastern Kittson County, Roseau River WMA, and an aerial survey of the east-central part of the state, in Minnesota; Sherwood Marsh, Grand River WMA, White River WMA, Comstock Marsh, Endeavor Marsh, Germania WMA, Widow Green Creek, and Navarino WMA in Wisconsin; Beaver Creek Area, Seney NWR, east of Pickford, Dryburg Area-Cartright Farm, and Luce County Airport in Michigan; Church Lake Prairie, Indian Prairie Marshall Prairie, Mud Prairie Lake, Orange Lake, Terry/Ledevith, and 301 Muck Farm in Alachua County, Florida; Buck Island Ranch, KD Ranch, and an 83-km driving route in Highlands County, Florida; Emerald Marsh, Emerald Muck Farm, Lake Serpentine and Rhoades Dairy in Lake County, Florida; Oklawaha Muck Farm in Marion County, Florida; Levy Prairie and Orange Grove Lake Prairie in Putnam County, Florida.

Counts at JPFWA and Haehnle were down 1,210 and 265 cranes, respectively, from peaks the preceding week (Fig. 1). Counting of cranes dispersed throughout the Okefenokee Swamp and Florida, and distinguishing "large" groups of migrant greaters from presumably smaller, more scattered groups of the resident Florida subspecies (*G. c. pratensis*), is problematic. Nevertheless, a count of only 355 probable migrants in Georgia and Florida suggests that significant migration did not occur past JPFWA and Haehnle before 26 October. The 355 cranes counted on wintering areas were subtracted from decreases at JPFWA and Haehnle of 1,475 to yield 1,120 uncounted cranes in transit south of JPFWA. The resulting total count was 14,385 cranes, of which 79% were counted at JPFWA and Haehnle.

The peak count at JPFWA in 1980 was unexpectedly early on 22 October (Fig. 1). Counts in Florida (Table 2) again suggested that significant migration past JPFWA did not occur before the peak count, when 14,250 cranes were counted on all northern concentration areas. Areas also censused on some dates, but where cranes were never seen, were Lunch Creek Marsh, Widow Green Creek,

Table 1. Census of eastern greater sandhill cranes, 2-4 November 1979.

Area	County	Number of cranes
WISCONSIN		
Crex Meadows Wildlife Area	Burnett	45
Freedland-Schwanebeck Farms	Clark	120
Pine Valley	Clark	30
Dike 17 Wildlife Area	Jackson	175
Necedah National Wildlife Refuge	Juneau	391
Sandhill Wildlife Area	Wood	612
MICHIGAN		
Baker Sanctuary	Calhoun	130
Haehnle Sanctuary	Jackson	627[a]
INDIANA		
Jasper-Pulaski Fish and Wildlife Area	Jasper-Pulaski	10,780[b]
GEORGIA		
Okefenokee National Wildlife Refuge	Ware	118
FLORIDA		
Paynes Prairie	Alachua	6
Starks Prairie	Marion	15
Between Kissimmee and St. Cloud	Osceola	58
Schearbrook Farms	Osceola	133
Grandin Prairie	Putnam	25
Cranes in transit south of JPFWA		1,120
TOTAL CRANES		14,385

[a] Down from 894 on 27 October.

[b] Down from 11,990 on 27 October.

Germania Marsh WA, White River WA, Puckyan Marsh, and French Creek WA in Wisconsin; Kawapa Prairie, Orange Lake Marsh, Levie Prairie, Putnam Hall Marsh, Oklawaha Muck Farm, River Ranch Acres, Hayman Ranch, and a 229-km route driven on 29 October along with 116 km repeated 3 November which included ranches of Deseret, Mormon, Kempter, Marcy, Adams, and Three Lakes WMA in Osceola County. Major movements of cranes through the Tennessee Valley region were noted during 1-5 and 20-25 November (W. K. James pers. comm.). First major departures of cranes from JPFWA apparently occurred during the 4th week in October. The peak count at Haehnle was not until 12 November, implying that at least 875 cranes were north of Haehnle on 22 October. Addition of 875 to the count on 22 October yields a total count of 15,125 cranes, 5% higher than in 1979. In 1980, 82% of the total was counted at JPFWA and Haehnle.

Despite similarity of census results in 1979 and 1980, proportion of the population actually counted remains unknown. The low peak count at JPFWA in 1977 (Fig. 2), 30% below the mean of adjacent years, obviously reflected weather or other influences and not population size. Counts at other areas in 1977 were not available, but if only counts at JPFWA were used, several years of such abnormal staging behavior could lower census figures by 3,000-4,000 cranes.

DISCUSSION

Measurements of 59 sandhill cranes at JPFWA all were within the range established for the greater subspecies (Melvin 1978, Lovvorn, unpubl. data). However, there is no evidence to deny or confirm that Canadian sandhill cranes (*G. c. rowani*) nesting in the Hudson Bay Lowlands (Lumsden 1971) pass through Michigan or Indiana, rather than flying west of the Great Lakes and wintering

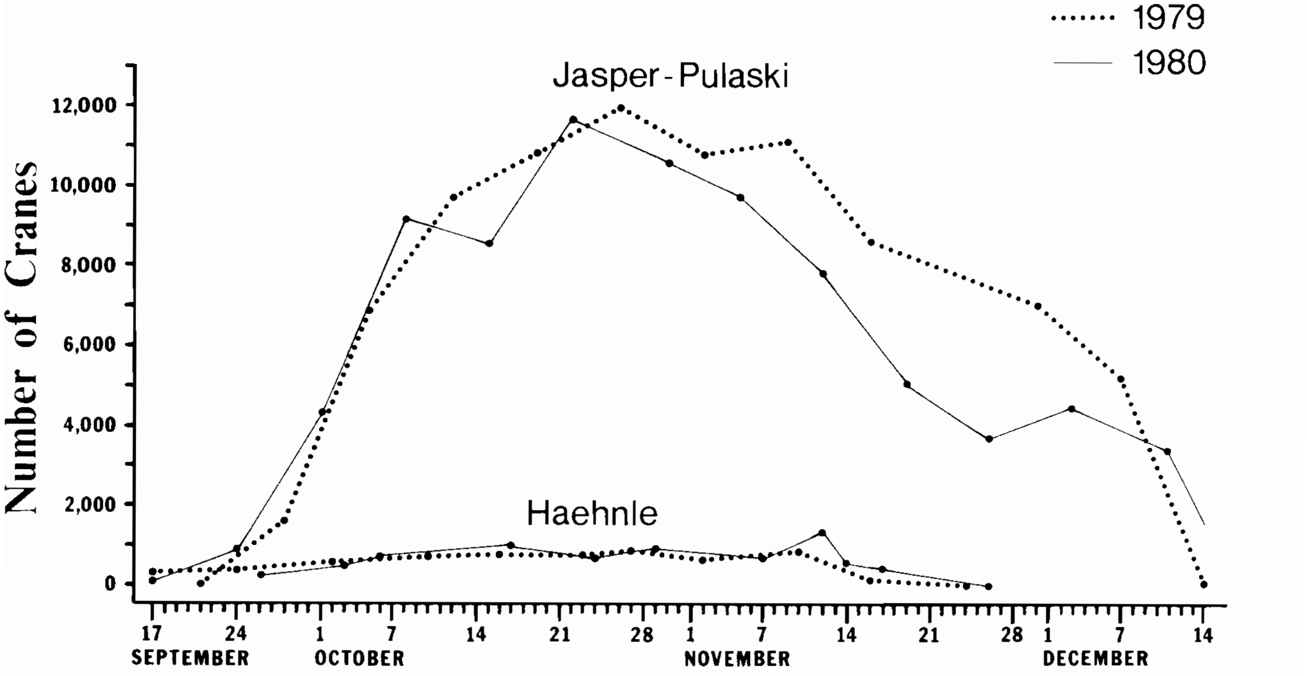

Fig. 1. Counts of sandhill cranes at Jasper-Pulaski Fish and Wildlife Area, Indiana, and Haehnle Sanctuary, Michigan, fall 1979 and 1980.

in the Central Flyway. Cranes nesting in east-central Minnesota apparently migrate through JPFWA (Crete and Toepfer 1978, unpubl.), but the proportion of cranes breeding in Manitoba and northwestern Minnesota, that winter in Florida (Nesbitt and Williams 1979) rather than Texas (S. M. Melvin pers. comm.), is unknown. The nesting range of the greater subspecies is also unknown north of the Great Lakes, but meager evidence suggests that cranes do not nest in significant numbers in the Precambrian Shield region (Lumsden 1971).

A comparison of census results with surveys of resident cranes in Michigan, Wisconsin, and Minnesota, to determine the proportion of the population nesting in Canada, is currently unjustified. Howard (1977) found that less than 50% of the cranes nesting in a central Wisconsin study area were reported by mail survey respondents, and concluded that reliable estimates of abundance were not possible with mail questionnaires. Such surveys constitute much of the current information on resident crane numbers in Wisconsin and Minnesota (Howard 1977; C. Henderson, unpubl. rep., Minnesota Department of Natural Resources, St. Paul, Minn., 1978).

As noted by Buller (1979), yearly variations in weather make it difficult to predict peak migration periods. Crane migration behavior relative to weather has been documented through radiotelemetry of sandhill cranes and monitoring of the similar common crane (*Grus grus*) by radar and observation from aircraft (Alerstam and Bauer 1973, Alerstam 1975, Melvin 1978, Crete and Toepfer 1978 unpubl., Pennycuick et al. 1979, Anderson et al. 1980 unpubl.). Cranes apparently use self-powered flight, compensating completely for wind, as a primary mode of migration, but take advantage of thermal updrafts whenever available (Alerstam 1975, Pennycuick et al. 1979). Optimal conditions for this mode of flight are tailwinds (15-25 km/hr), initially clear skies with high insolation at the surface, and cold, dry air advecting over warmer, moister ground. Such weather in fall typically follows passage of a cold front.

Optimal conditions apparently can stimulate migration simultaneously over broad areas (Bowman and Whitman 1972, Nesbitt 1975), and major migration flights are expected to occur during days when such weather prevails. However, because cranes use thermals opportunistically and are not dependent on them, migration may occur under cloudy conditions and even at night (Alerstam and Bauer 1973, Beason 1978, Crete and Toepfer 1978 unpubl., Anderson et al. 1980 unpubl.). In this study, attempts to relate chronology of migration to synoptic weather patterns were unsuccessful because conditions producing thermals are complex and crane counts were too infrequent to indicate differential migration rates. Hence, weather patterns could not be used to infer when major migration

Table 2. Fall 1980 census of eastern greater sandhill cranes.

State, Area, and County	October					November		
	2	10	17	22	29	1-3	5	12
MINNESOTA								
Agassiz NWR, Marshall	1,100			[a]	0			
WISCONSIN								
Crex Meadows WA, Burnett				325	260			
Freedlund-Schwanebeck Farms, Clark				135	110			
Mead WA, Marathon				47	0			
Navarino WA, Shawano		6	4	0	0			
Sandhill WA, Wood	955	942		667	435		130	
Dike 17 WA, Jackson	350	350	300	350	200			
Necedah NWR, Juneau				136	142		27	0
Leola Marsh, Adams				40	0			
Comstock Marsh, Marquette				0	3			
Endeavor Marsh, Marquette					12			
Fox River Marsh NWR, Marquette	250				0			
Lake Puckaway, Green Lake					3			
MICHIGAN								
Beaver Creek Area, Oceana		63		0	0			
Baker Sanctuary, Calhoun					117			80
Haehnle Sanctuary, Jackson	466	800	990	670	897		652	1,300
Cranes north of Haehnle Sanctuary, Jackson				875	648		648	
INDIANA								
Jasper-Pulaski FWA, Jasper-Pulaski	4,340	9,215	8,563	11,696	10,619		9,730	7,769
Atterbury FWA, Johnson				150[b]		250[b]		
TENNESSEE								
Tellico Reservoir, Monroe						170[b]		
NW of Byrdstown, Pickett						304[b]		
Dayton, Rhea						100[b]		
Tellico Reservoir, Loudon						15[b]		
Watts Bar Reservoir, Roane								110[b]
GEORGIA								
Piedmont NWR, Jones						7[b]		
Okefenokee NWR, Ware (census routes varied between weeks)				34	21		91	28
FLORIDA								
Paynes Prairie, Alachua						70		
Levy Lake, Alachua						7		
Emerald Marsh, Marion						138		
Emerald Muck Farm, Marion						36		
Lake Kissimmee Park, Polk						40		
Judge Dairy Farm, Osceola						9		
TOTAL	7,461	9,215	9,857	15,125	14,662[c]	1,146	11,278	9,287

[a] Cranes present but numbers unknown on 22 October on Agassiz NWR, Thief Lake WA, NE of Felton, and E of Borup, Minnesota.

[b] Cranes observed in flight.

[c] Includes cranes counted north of Indiana on 29 October plus cranes counted south of Indiana 3 November.

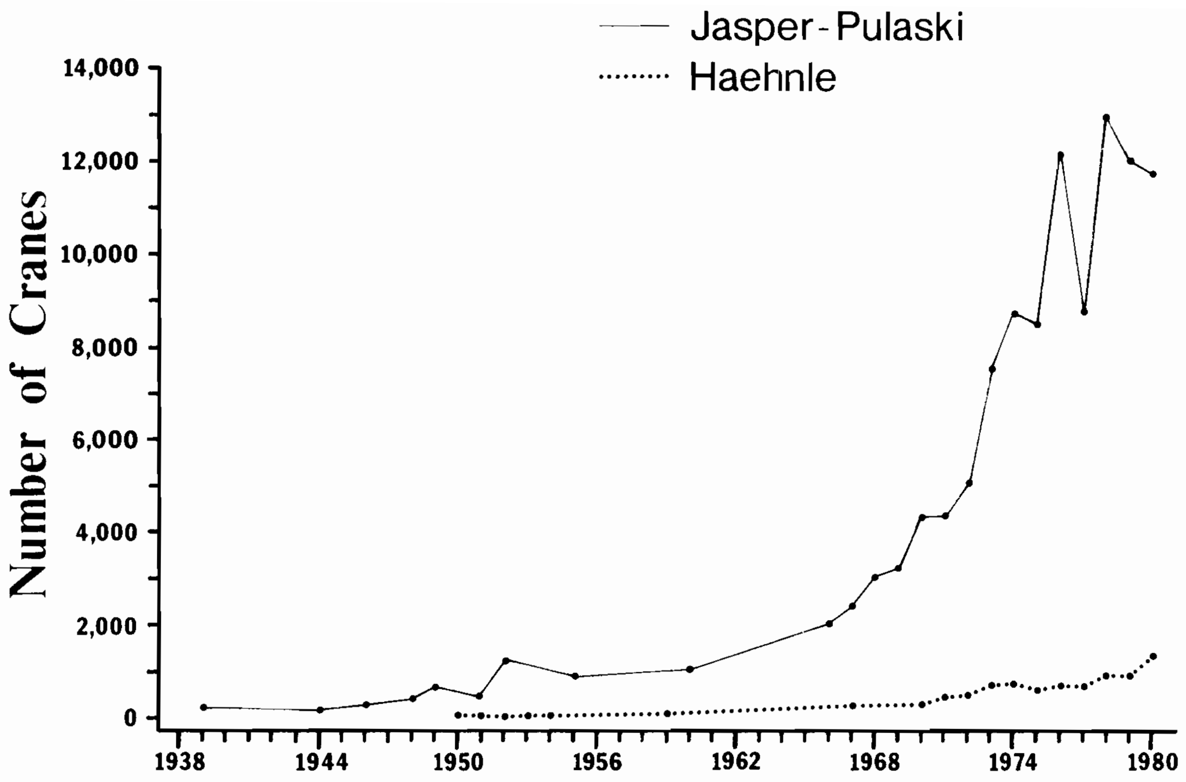

Fig. 2. Peak fall counts of sandhill cranes at Jasper-Pulaski Fish and Wildlife Area, Indiana, 1939-1980, and Haehnle Sanctuary, Michigan, 1950-1980 (includes data from Hoffman 1977).

movements probably occurred, and to estimate consequent error associated with counts on particular dates.

Moreover, radar studies have shown that although some flocks fly as high as 2,000 m above the ground, common cranes seldom migrate at altitudes above 1,000 m (Alerstam 1975, Pennycuick et al. 1979). If sandhill cranes conform to this pattern, a high proportion of migrating flocks may be visible from the ground. Alerstam and Bauer (1973) found that ground observations of migrating cranes corresponded closely with migration activity measured with radar. Local sightings collected by cooperators in different regions may help infer periods of major crane movements.

Budget constraints currently make unfeasible the simultaneous or weekly counts of cranes on all concentration areas in Wisconsin (C. D. Besadny pers. comm.). During this study, peak counts at JPFWA and the Haehnle Sanctuary accounted for 81% of all cranes censused. However, the 10-year refuge status of crane roosts at JPFWA has been gradually withdrawn since 1978, and all major roosts are now subject to waterfowl hunting. Hunting disturbance causes immediate migration departures from areas in Minnesota, Wisconsin, and Michigan (Walkinshaw and Hoffman 1974, Crete and Toepfer 1978 unpubl., Melvin 1978), and marked avoidance of hunted roosts at JPFWA (Lovvorn and Kirkpatrick 1981). Recent resumption of waterfowl hunting may within several years alter the representativeness of crane counts at JPFWA. Consequently, future counts at JPFWA and the Haehnle Sanctuary should not be considered as indicators of population trends without complementary counts throughout the migration corridor.

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DISTRIBUTION OF SANDHILL CRANES WINTERING IN MEXICO

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Abstract: Sandhill cranes wintering in Mexico have been recorded as far south as the Yucatan Peninsula; the states of Jalisco, Michoacan, Guanajuato, San Luis Potosi, and Puebla in the interior; and Sinaloa and Nayarit on the west coast. Although cranes winter over a large area of Mexico, population surveys begun in January 1959 and special studies initiated in January 1962 indicate that 90-95% of the population is associated with 10 or fewer favored sites in the Central Highlands region. These sites include lagunas and saline playas in mountain basins (*bolsons*), and lagos (lakes) and reservoirs (presas) associated with active river systems.

Sandhill cranes have probably wintered in Mexico for centuries; however, records of their occurrence before the 20th century are found primarily in the writings of adventurers and explorers of the early 1800's. For example, George August Frederick Ruxton (in Hafen 1950:128-150) was a young Englishman who traveled and explored Spain, Africa, Canada, Mexico, and the American West. Writing of his travels in Mexico in 1846 he noted on 4 October between Somrerete, Zacatecas, and Durango, ". . . We passed through a flat country, entirely inundated, and alive with geese and gruyas. The latter bird, of the crane species, is a characteristic feature in the landscape of this part of Mexico. The cornfields are visited by large flocks and as they fly high in the air, their peculiar melancholy note is constantly heard, both in the day and night, booming over the plains."

Ruxton also noted in November 1846, ". . . Chihuahua is a paradise for sportsmen . . . Of birds--the faisan, commonly called paisono, a species of pheasant: the quail, or rather a bird between a quail and partridge, is abundant; while every variety of snipe and plover is found on the plains, not forgetting the gruya, of the crane kind, whose meat is excellent . . . ."

As interest in the management of sanhill cranes increased, greater efforts were expended to locate and describe the areas utilized by cranes wintering in Mexico. These efforts were expended by biologists, ornithologists, and others for a variety of reasons and their findings appear in unpublished manuscripts, books, progress reports, and other sources. The hunting of sandhill cranes in the Central Plains of the United States and the Republic of Mexico continues to foster interest in the management of this species. Consequently, this paper will attempt to bring together all the information available on the distribution of sandhill cranes wintering in Mexico.

Over the years, wintering flocks have been reported to be widely scattered in Mexico. They have been observed as far south as Sinaloa and Nayarit on the west coast; in Jalisco, Michoacan, Guanajuato, San Luis Potosi, and Puebla in the interior; and to the Yucatan Peninsula on the east coast. However, the Central Highlands region in Chihuahua and Durango includes the principal wintering areas.

DISTRIBUTION AND DENSITY

Special Studies and Surveys

Saunders and Leopold (in Leopold 1972:281) reported wintering sandhill cranes on the Colorado River Delta; on the llanos (plains) near El Carmen, Puebla; and in the arid basins and valleys north and west of the capital of San Luis Potosi. Friedmann et al. (1950:82) and Leopold (1959:281) also reported sandhill cranes wintered as far south as the Yucatan Peninsula on the east coast.

Cooke (1914:10, Bent (1926:251), Ridgway and Friedmann (1941:20), Walkinshaw (1949:114), Friedmann et al. (1950:82), and Leopold (1959:281) reported wintering sandhill cranes in the interior states of Jalisco, Michoacan, Guanajuato, and Puebla. Walkinshaw (1949:113) and G. Hortin Jensen (in Lewis 1977:20), Flyway Biologist, U.S. Fish and Wildlife Service, reported wintering sandhill cranes on the west coast to Sinaloa and Nayarit.

Boeker and Baer (1962, 1963), U.S. Fish and Wildlife Service, conducted surveys in January 1962 in central and western Mexico, and in central and eastern Mexico in January 1973. Sandhill cranes were not observed at Lago Navajoa or Lago Obregon (Sonora) nor Lago de Chapala or Laguna de Sayula (Jalisco) in 1962. No sandhills were recorded at Presa Cardenas (El Palmito or Rio de Oro), but 350 birds were observed at Laguna de Santiaguillo (Durango). In the State of Chihuahua, 975 sandhills were recorded at Palomas, 500 at Galeana, 850 at Laguna Bustillos, 13,500 at Laguna de Babicora, and 4,300 at Lago Toronto. Sandhill cranes were not observed at Casas Grandes or Lago Tascitic. Laguna Guzman, Laguna de Santa Maria, and Ojo Laguna were dry.

In 1963, Boeker and Baer tallied 15 sandhill cranes at Presa Cardenas and none were observed at Laguna de Santiaguillo or Lago Orilla (Durango). Laguna de Mayran (Coahuila) was dry. Sandhill cranes were not seen at Laguna de Yuriria, Laguna de Cuitzeo, or Lago de Patzcuaro (Guanajuato). Sandhill cranes were not seen at Presa M. Comacho but 230 birds were counted in the Carmen Marshes (Puebla). Sandhills were not observed near O'Campo (Tamaulipas). In Chihuahua, 1,000 birds were tallied at Palomas, 150 at Galeana, 25,000 at Laguna Bustillos, 5,000 at Laguna de Babicora, and 700 at Lago Toronto. Sandhills were not observed at Casas Grandes.

In January 1971, Knoder and others (Knoder et al. 1980) recorded 30 sandhill cranes along the coast of Sonora south of Estero de Lobos. In January 1972, they tallied 224 birds in the Marismas Nacionales, a vast network of mangrove-bordered lagunas, mud flats, and several river deltas between Mazatlan, Sinaloa, and San Blas, Nayarit. In February 1974 and 1975, they recorded 174 and 125 sandhills, respectively, at Laguna de Santiaguillo, Durango.

In January 1973, E. G. Bizeau and R. C. Drewien (Drewien 1973) of the U.S. Fish and Wildlife Service and University of Idaho, respectively, surveyed major wintering sandhill crane sites in western Chihuahua and Durango, and along the west coast in the states of Nayarit, Sinaloa, and Sonora. Cranes were not observed along the west coast. In Durango, no birds were observed at Presa Cardenas but 60 birds were seen at Laguna de Santiaguillo. In Chihuahua, 45 sandhills were tallied at Laguna Colorada, 11,495 at Laguna de Babicora, 160 at Laguna de los Mexicanos, and 58 at Lago Toronto. Sandhills were not observed at Tintero Reservoir or Presa Guerrero.

In January 1976, C. Eugene Knoder and David Blankinship of the National Audubon Society, accompanied by Drewien, made an aerial survey of the principal sandhill crane wintering sites in Chihuahua and Durango, and the Marismas Nacionales. Drewien (1976a) reported the greatest number of wintering sandhills was tallied in Chihuahua: 16,000 at Laguna de Babicora, 2,210 at Lago Toronto, 1,135 at Laguna Ascension, 850 at Laguna Victoria, 290 at Laguna de los Mexicanos, 175 at Buenaventura, 50 at El Penol, 20 at Presa Guererro, and 4 at Galeana. No birds were observed at Laguna Guzman, Casas Grandes, or Laguna Bustillos. In Durango, 83 sandhills were tallied at Presa Cardenas and 26 at Laguna de Santiaguillo. None were observed at Canatlan or Marcillo. Along the Pacific Coast, 425 were tallied in the Marismas Nacionales.

In December 1976, Drewien (1976b) accompanied Flyway Biologist J. Voelzer, U.S. Fish and Wildlife Service, on a goose survey in the Central Highlands region at which time he recorded wintering sandhill cranes. He reported nearly 36,000 birds were tallied in Chihuahua and 900 were recorded at wintering areas in Durango.

In January 1977, Drewien (Drewien 1977) again accompanied C. Eugene Knoder, National Audubon Society, on an aerial survey of the principal sandhill crane wintering sites in the Central Highlands region and the Marismas Nacionales. He reported that more than 31,000 sandhills were tallied at sites in Chihuahua; 225 were recorded at Laguna de Santiaguillo, Durango, and 85 were observed in the Marismas Nacionales.

During 13-14 January 1978, Bizeau and Drewien (Drewien 1978) conducted an aerial survey of major sandhill crane wintering sites in the highlands of northwestern and west-central Chihuahua. During 26-27 January 1978, Drewien accompanied Knoder on an aerial survey in southern Chihuahua and northern and central Durango. Nearly 5,800 sandhills were tallied in northwest and west-central Chihuahua, nearly 4,000 birds were recorded in southern Chihuahua, and 990 were observed in Durango.

On 4 February 1979, Drewien tallied 2,170 sandhills 8-18 km south of Ascension, Chihuahua. During 7-9 January 1981 he recorded 3,488 birds in the Rio Santa Maria valley near Galeana, 3,800 near Ascension, and 850 birds at Laguna de los Mexicanos.

The results of all the special studies and surveys are summarized in Table 1. The following areas were dry or without cranes present when surveyed: In Chihuahua State--Lago de Guzman in December 1976 and 1978; Lago Delicias, December 1976; Las Madanos Carbonera, December 1976; Matachi 1978, Santa Gertrudias 1978; Lago de Santa Maria, December 1976; In Durango State--Marcillo, December 1976, 1977, and 1978; Lago Orilla in 1962; In Coahuila State--Lago de Mayran, 1962; In Guanajuato State--Lago de Yuriria, Lago de Guitzeo, and Lago de Patzcuaro, all in 1962; In Puebla State--Presa M. Comacho in 1962; In Tamaulipas State--O'Campo in 1962.

The following items were not included in Table 1 because of table size limitations. In January of 1974 and 1975, 174 and 125 cranes were censused, respectively, at Lago de Santiaguillo, Durango State. In Carmen Marshes, Puebla State, 230 cranes were present in January 1962. Presa Guerrero, Chihuhua State, was censused in December 1976 and January 1978 but without cranes. Casa Grandes, Chihuahua State, was censused December 1976 and January 1978, but lacked cranes except 15 in December 1976.

Regular Surveys

Beginning with the 1959 annual midwinter waterfowl survey in Mexico, conducted by U.S. Fish and Wildlife Service flyway biologists, wintering sandhill cranes were tallied in the Central High-

Table 1. Numbers of wintering sandhill cranes recorded in northern Mexico during special studies and surveys, 1962-63, 1973, 1976-78, 1981.

Mexican state and area	Jan 1962	Jan 1963	Jan 1973	Jan 1976	Dec 1976	Jan 1977	Jan 1978	Jan 1981
Chihuahua								
Lago Palomas	975	1,000			0	0	1,475	
Laguna de la Ascension				1,135	1,430	2,050	2,155	3,800
Galeana	500	150		4	1,297	1,630	775	3,488
Buenaventura				175				
Laguna Babicora	13,500	5,000	11,495	16,000	30,000	24,750	0	
Laguna Bustillos	850	25,000		0	0	0	0	
Laguna de Encinillas							765	
Laguna de los Mexicanos			160	290	2,440	1,550	125	850
Laguna Colorado			45					
Tintero Reservoir			0		8		520	
Laguna Victoria				850	190	85		
Durango								
Laguna Canatlan				0	150	0	650	
Presa Cardenas	0	15	0	83	50	0	290	
Laguna de Santiaguillo	350	0	60	26	650	225	50	
Sinaloa-Nayarit								
Marismas Nacionales				425		85		

lands region of Chihuahua and Durango. During the 1959-65 surveys, the numbers of wintering sandhills ranged from 304-5,266. During the 1970 survey, 1,380 wintering sandhills were tallied, and the 1975 survey recorded 11,113 birds. Surveys conducted from 1977 through 1981 tallied between 5,745 and 33,315 wintering sandhill cranes (Table 2).

DESCRIPTION OF PRINCIPAL WINTERING AREAS

The Central Highlands region of Mexico is a large plateau, rising from 3,000-4,000 feet (900-1,200 m) elevation at the U.S.-Mexico border to about 8,000 feet (2,400 m) near Mexico City. Most of it is an arid, rolling plain interrupted by ranges of foothills and low mountains. Geological forces created a large number of lakes which have been used by wintering waterfowl, sandhill cranes, and other water birds. However, impoundments, irrigation, and increased municipal and industrial use have in recent years altered the hydrology and water levels have become highly variable. In drought years some of the lagunas become completely dry.

Many of the lagunas in the northern portion of the Central Highlands region occur in basins called *bolsons* (Saunders and Saunders 1981) and are saline playas having no outlet. The lagos (lakes) of the southern portion are usually part of an active river system and some were created by dams (presas). The following sites represent the current principal sandhill crane wintering areas within the Central Highlands region of Mexico (Fig. 1). Descriptions are based on Boeker and Baer (1962) and Saunders and Saunders (1981).

Table 2. Numbers of wintering sandhill cranes recorded in northern Mexico during annual midwinter waterfowl surveys, 1959-65, 1970, 1975, and 1977-81.

Area	1959	1960	1961	1962	1963	1964	1965	1970	1975	1977	1978	1979	1980	1981
Palomas					12					285				
L. de la Ascencion											50	2,555		
L. de Santa Maria					10									
L. Babicora			750		87	2,562	4,136	150	10,378	3,865	1,470	23,470	2,550	5,350
L. Bustillos			35	7		150	1,100	25						
L. de los Mexicanos		282	70	7		1,205		1,140	155	4,250	3,500	2,600	8,045	
L. Toronto	253	311	93	1,125	45		30		350	65	455	20		
L. de Santiaguillo	2,445	6			150	650		15		325	15	15		
L. de Encinillas		60								90	705	285		
L. de Patos			100											
La Cruz			70						30			2,510		
Don Martin			155	59										
Rio del Oro			10											
Villa de Cos			65					50	200	345	250	250		
Santa Gertrudis						10						800		
Villa Union											900			
Saldadito											30			
North Durango												15		
South Durango												750		
Santo Domingo												45		
L. Victoria													1,680	

Fig. 1. The principal sandhill crane wintering areas within the Central Highlands region of Mexico.

State of Chihuahua

Lago Palomas--A natural, spring-fed lake in a wide, flat valley about 4 miles (6 km) south of the town of Palomas. Birds utilizing this area frequently feed in sorghum and alfalfa fields near Columbus, New Mexico.

Laguna de la Ascension--A shallow, saline playa located near the community of Ascension.

Laguna de Guzman--A sump lake, frequently dry, on the Rio Casas Grandes about 60 miles (95 km) south-southeast of Columbus, New Mexico.

Laguna de Santa Maria.--A sump lake, frequently dry, on the Rio Santa Maria about 65 miles (104 km) southwest of El Paso, Texas. L. J. Goldman (in Saunders and Saunders 1981) wrote about these lagunas--Guzman and Santa Maria--in 1942, "Formerly celebrated as wintering grounds for geese, cranes and ducks, they have in recent years been much reduced in superficial area by water diversion, and during periods of dry cycles by the effects of drouth . . . . "

Casas Grandes.--Two small reservoirs 2-3 miles (3-5 km) east of the town of Nuevo Casas Grandes. The reservoirs are fed by the Nuevo Casas Grandes River and the impounded water is used to irrigate a small valley lying 3-5 miles (5-7 km) northwest of the city.

Galeana.--A small spring-fed marsh located about 5 miles (7 km) northeast of the village of Galeana. Wintering sandhills feed in adjacent cornfields.

Laguna de Babicora.--This laguna, in the La Babicora Valley, is about 115 miles (184 km) northwest of the capital city of Chihuahua. It and its associated sloughs and shallow lakes occur in a mountain valley that has no outlet. The valley comprises 450-600 square miles (1,150-1,530 km^2) and large acreages of corn, oats, and beans provide excellent feeding areas for wintering sandhills. L. J. Goldman (in Saunders and Saunders 1981) referred to the valley as ". . . one of the greatest sandhill crane wintering grounds on the North American Continent . . . ."

Laguna Bustillos and Laguna Tascitic.--These lagunas are located in the Bustillos Valley and Laguna Bustillos is about 45 miles (70 km) west of the capital city of Chihuahua. Bustillos Valley is separated from Babicora Valley by a low range of mountains and collectively the 2 valleys comprise about 1,300,000 acres (520,000 ha) of excellent habitat for wintering sandhill cranes.

Laguna de los Mexicanos.--This laguna is about 60 miles (100 km) southwest of the city of Chihuahua. It occurs in a closed mountain basin, or *bolson*, and has a surface area of about 10,000 acres (4,050 ha) when full. Corn and cereal grains are grown on the surrounding land by a local Mennonite colony and the harvested fields provide excellent food for wintering sandhills.

Lago Toronto.--This lago is about 75 miles (120 km) southeast of the city of Chihuahua. It is a long, narrow irrigation reservoir on the Rio Conchas. Some cultivated crops, primarily corn, provide the feeding area for wintering cranes.

State of Durango

Presa Cardenas.--This reservoir, also called Rio de Oro or El Palmito, is on the Rio Nazas. It stores irrigation water for the cotton-growing area near Torreon and is about 85 miles (135 km) west of that city. The only cultivated lands in the vicinity occur along the river on the upper portion of the reservoir.

Laguna de Santiaguillo.--This laguna occurs in an elongated natural basin, the southern end of which is about 43 miles (70 km) north of the city of Durango. The laguna was formed by an earthen dam across the middle of the basin; the northwest laguna is called Santiaguillo and the southeast laguna is locally known as Guatimape or Canatlan. A local Mennonite colony grows corn and oats on adjacent lands and the stubble fields are utilized by wintering sandhill cranes.

The above described areas are utilized by 90-95% of the sandhill cranes that currently winter in Mexico, and the degree of utilization is determined by water levels. During low water or drought years, sandhills seek out more favorable areas such as Laguna Babicora, Laguna Bustillos, Laguna Tascitic, Laguna de los Mexicanos, and Laguna Toronto.

SUMMARY

Although sandhill cranes wintering in Mexico have been noted in some of the writings of the early 1800's adventurers and explorers, the extent of their distribution and density was not studied until interest developed in the management of cranes. Due to sandhill crane hunting seasons in the Central Plains of the United States and the foster-parent sandhill crane-whooping crane restoration project in the Rocky Mountains, surveys and studies were begun in January 1962 to delineate areas utilized by sandhill cranes wintering in Mexico. These surveys and studies indicate that the Central Highlands region of Chihuahua and Durango host the bulk of the current wintering population, and that 90-95% of this population can be found at about 10 favored sites.

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STAGING OF SANDHILL CRANES ON THE EASTERN COPPER RIVER DELTA, ALASKA

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Abstract: Over 18,000 lesser sandhill cranes (*Grus canadensis canadensis*) in fall and over 9,800 in spring were counted migrating through the eastern Coppper River Delta in south coastal Alaska. Peaks of migration occurred during the last week of April and mid- to late September of 1979 and 1980. Among 43 lesser sandhill cranes banded and neck-collared on wintering grounds at Merced National Wildlife Refuge, California, up to 4 were resighted on the study area. Others have been resighted in Oregon during spring migration, suggesting an all-Pacific Flyway migration route. Age ratio observations of cranes indicated 7% juveniles in the fall of both years. Cranes fed almost exclusively on the bulbs of the arrow grass *Triglochin palustris* while staging in the fall. Roost sites included intertidal mudflats, grassy meadows, and shallow lakes. Staging cranes fed in moist openings dominated by mosses, grasses, and the sedge *Carex ramenskii*. The 1964 Alaska Earthquake uplifted the study area over 2 m and above tidal influence. As a result, expansion of shrub growth is threatening present crane habitat.

The delta of the Copper River in south coastal Alaska forms an expanse of over 650 km^2 of wetland habitat along the otherwise steep and rocky coastline in the northeastern Pacific Ocean. Islieb and Kessel (1973) regarded sandhill cranes as common to abundant spring and fall migrants along the northern Gulf of Alaska coast and noted that they often lingered for several days on the marshes of the Copper and Bering river deltas in fall. Local inhabitants of the region have noted little use of the western portion of the Copper River Delta by migrant cranes, but high use of the eastern portion. This study was undertaken to determine the abundance, phenology, and migration routes of sandhill cranes utilizing the Eastern Copper River Delta (ECRD), and to investigate age ratios, food habits, and habitat preferences of staging cranes. Observations on the study area were made from 27 April to 22 October 1979 and from 17 April to 19 May and 18 August to 20 October 1980.

Funding for this project was provided by contract 14-16-0009-79-079, Accelerated Research Program for Migratory Shore and Upland Game Birds, U.S. Fish and Wildlife Service. Support during the 1st year of the study was also provided by the U.S. Forest Service, Chugach National Forest, and logistics support for banding operations in California came from the Portland Area Office, U.S. Fish and Wildlife Service and the San Luis National Wildlife Refuge (NWR) Complex.

Peter G. Mickelson, Wildlife and Fisheries Program, University of Alaska, obtained funding and offered extensive guidance throughout the course of the project. Garvan Bucaria, U.S. Forest Service, Cordova, provided logistics support; and Mariko Yamasaki, James Hawkings, and Donita Haynes offered expert assistance in the field. Richard D. Bauer, U.S. Fish and Wildlife Service, Portland, and the staff of Merced NWR, particularly Larry Rauen and Raymond Fuller, were essential to the success of banding operations.

STUDY AREA AND METHODS

The Copper River Delta lies east of the town of Cordova and within the Chugach National Forest. It is managed jointly by the U.S. Forest Service, Alaska Department of Fish and Game, and Alaska Department of Natural Resources. The delta was designated a critical habitat zone by the Alaska legislature in 1978 due to extensive areas of intertidal and upland habitats utilized by water birds and other wildlife species (Bucaria, G. P. 1979. Copper River Delta area wildlife resource review. Unpubl. rep., Chugach Natl. Forest, Cordova, Alaska. 162 pp.). The ECRD study area encompassed wetland habitats bounded on the west by the Copper River, the north and east by the Ragged Mountains, and the south by the Gulf of Alaska (Fig. 1). The area consisted of a tidal lagoon with associated mudflats and marshlands bisected by a network of intertidal sloughs.

I delineated 4 major habitats following Kessel (1970a). In order of increasing tidal influence they were: (1) Medium Shrub--dominated by sweetgale (*Myrica gale*) and sedges (*Carex* spp.) with large shallow lakes and small streams lined with alder (*Alnus sinuata*), sitka spruce (*Picea sitchensis*), and cottonwood (*Populus trichocarpa*); (2) Wet Meadow--a mosaic of plant communities dominated by mosses, sedges, and grasses interspersed with alder and willow (*Salix* spp.) scrub; (3) Salt Grass Meadow--dominated by salt grass (*Puccinellia* spp.), sedges, *Plantago maritima*, and *Potentilla egedii*; and (4) Intertidal Mudflats--inundated by saltwater twice daily and devoid of vegetation.

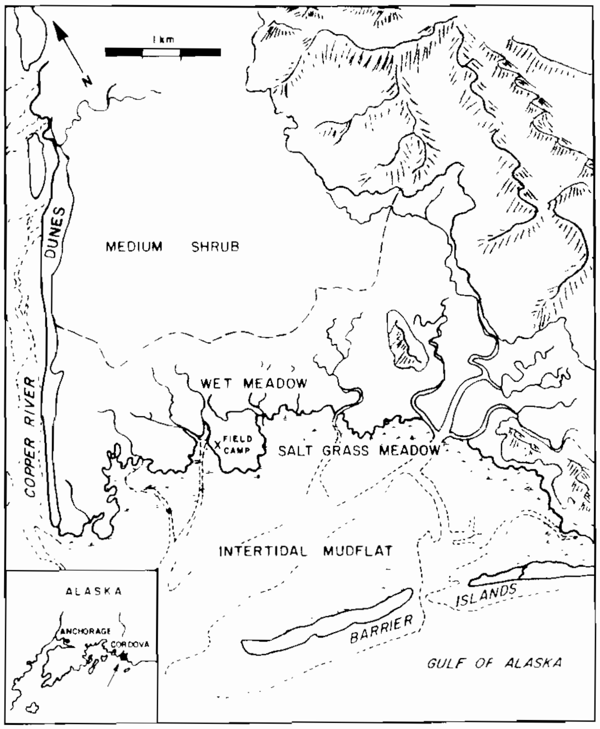

Fig. 1. Major habitat types of the eastern Copper River Delta (dashed line delimits Medium Shrub and Wet Meadow types).

The Great Alaska Earthquake of 1964 uplifted the study area approximately 2 m (Krauskopf 1971), restricting tidal flooding to slough channels within the Wet Meadow. The resultant freshwater regime allowed invasion by shrubs and formation of a dense ground cover of mosses. The uplift also allowed new salt marshes, represented by the Salt Grass Meadow, to develop on the higher intertidal mudflats.

Access to the ECRD was restricted to boats or float-equipped aircraft and all travel during the study was by foot or small boat. Observations of migrating and staging sandhill cranes were made from a 4-m-high tower located at the field camp. Watches of 1 hour duration every 2 hours were conducted in spring and fall. Frequency and duration of watches varied depending on weather, intensity of migration, and other activities. Following the suggestions of Lewis (1979), age ratios were tallied only under conditions where adults and juveniles were clearly discernible by head coloration. Age ratio counts were taken mainly on flocks of cranes attracted within view of observers by placement of 3 taxidermy-mount crane decoys near the camp site.

Food habits were determined by collecting birds and from gizzards and gullets obtained from hunters. Food samples were preserved immediately in 10% formalin. Food items were measured volumetrically by water displacement, and gullet contents were later oven-dried at 60°C for 48 hours. Frequency of occurrence was calculated as the percentage of samples containing a food type. Percentage by volume is expressed by the aggregate-percentage method (Swanson et al. 1974). Percentage by dry weight was also calculated for gullet contents by dividing the dry weight of a food item by total dry weight of all foods. To assess habitat preferences within the Wet Meadow, 1-m^2 vegetation plots were taken at intervals throughout this habitat type, and similar plots were taken at crane feeding sites immediately after use by cranes. Vegetation plots were analyzed for soil moisture, surrounding shrub cover, and percent plant cover by species.

In an attempt to determine migration routes of ECRD cranes, lesser sandhill cranes were captured on wintering grounds in the San Joaquin Valley, California, during February and March of 1980 at Merced NWR. Cranes were captured using three 20- by 10-m and one 30- by 15-m recoilless rocket nets baited with corn and 6 taxidermy-mount crane decoys. Captured birds were marked with standard aluminum leg bands and red plastic neck collars and leg bands. Both color markers were 62.5 mm high and contained white alpha-numeric codes.

RESULTS AND DISCUSSION

Abundance and Phenology of Migrants

Sandhill cranes 1st appeared on the ECRD on 22 April 1979 (J. S. Hawkings, pers. comm.) and 19 April 1980. Numbers of cranes passing west (northward migration) increased and peaked during the last few days of April and the 1st few days of May (Fig. 2). Flock sizes ranged from 2 to 600 birds ($\bar{x}$ = 83) and most overflew the ECRD in spring. However, flocks of cranes were daily present on the ground, and up to 500 birds occasionally roosted overnight on the study area. After the 1st week of May, numbers of passing cranes diminished rapidly and, in both years, approximately 200 cranes remained on the ECRD for 1 week or more during mid-May. One of these cranes, a female collected on 11 May 1980 for food habits analysis, contained undeveloped ovaries, suggesting these lingering birds were nonbreeders. Virtually all sandhill cranes had departed ECRD by 15 May of both years. A few pairs of cranes may occasionally nest on the Copper River Delta (Islieb and

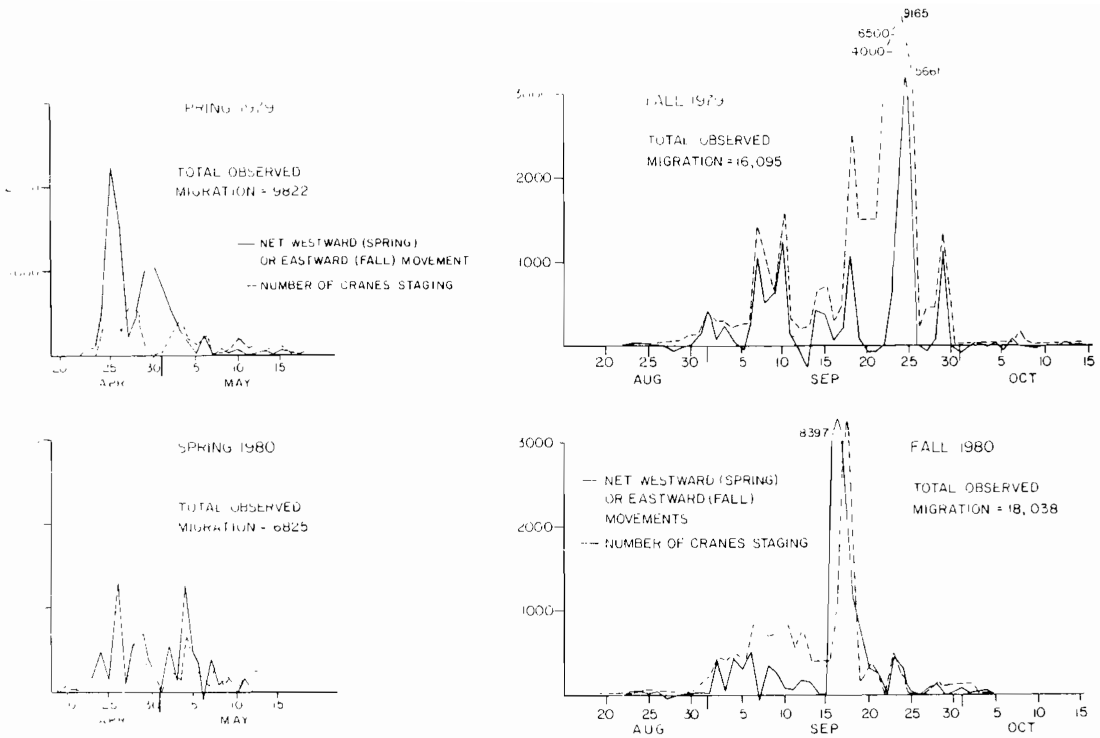

Fig. 2. Net movement of sandhill cranes (solid lines) west (northward migration) in spring, and east (southward migration) in fall, past the field camp. Numbers of staging cranes are represented by the dashed lines.

Kessel 1973), but evidence of nesting was not observed on the ECRD study area during the summer of 1979.

Fall migration through the area was more prolonged. Cyclonic storms originating in the Gulf of Alaska frequently produced strong southeast winds and heavy rain throughout the fall staging period. As noted by others, sandhill cranes seem reluctant to migrate into strong headwinds and poor visibility (Walkinshaw 1949, Kessel 1979b). Carcasses of cranes examined during fall on the ECRD generally contained large amounts of subcutaneous and body cavity fat, except for some juveniles that contained few fat reserves. Weather factors plus poorer condition of some juveniles may contribute to longer staging times in the fall. Sandhill cranes first arrived on the study area on 23 August 1979 and 19 August 1980. Numbers of staging cranes built to several hundred by 1 September and peaked during mid- to late-September (Fig. 2).

Flock sizes in fall averaged 90 birds (range 1 to 7,000). Due to lack of a number of marked individuals, the duration of stay of individual crane flocks on the staging grounds can only be estimated. During 1979 only 2 small flocks of cranes were observed overflying the study area without stopping. Other cranes observed remained at least overnight and some up to 7-10 days. Persistent poor weather conditions in September of 1979 probably induced the longer staging times. In 1980, approximately 8,000 cranes overflew the study area during favorable northwest winds and clear skies of 16 September. Major crane passage farther east at Yakutat, Alaska, occurred on 18 September (M. R. Petersen, pers. comm.). This large group of birds must have stopped somewhere east of the ECRD, such as the nearby Bering River Delta or smaller wetlands near Yakutat. Crane populations dropped below 100 birds after the 1st week of October and only stragglers remained past mid-October.

Arrival of cranes on the study area in fall often occurred within 1 or 2 hours of sunset, with many birds flying directly to roost sites upon arrival. Crane departures from the study area usually coincided with clearing skies and building air thermals which often occurred at mid-morning.

The maximum number of cranes actually observed passing the observation tower at the field camp was 18,038 cranes during fall of 1980. Fewer numbers were observed in spring when the birds utilized a wider migration corridor, reducing detection rates of passing flocks. On several occasions in spring, migrating flocks of cranes could be heard but not counted as they passed over the study area at night. I estimate approximately 20,000 sandhill cranes passed through the ECRD during fall migration.

Migration Routes

During the 1979 field season, marked sandhill cranes were not observed among the over 4,000 cranes seen close enough to detect color markers. This failure suggested that, because of the recent extensive color-marking of lesser sandhill cranes in the Central Flyway (P. A. Vohs, Jr., in litt.), these cranes may belong to a separate population. Most migratory water birds appearing on the Copper River Delta are Pacific Flyway migrants; consequently, it seems most likely that the cranes may also be using a Pacific Flyway route.

Forty-three lesser sandhills were marked at Merced NWR during winter of 1980. Five of these cranes with red neck collars were subsequently sighted in Oregon: 3 near Burns during March 1980, and 2 near Bonanza on 11 April 1980 (C. D. Littlefield and C. R. Ely, in litt.). All marked birds were members of flocks of 200 to 600 lessers. During spring migration on the ECRD study area, 2 cranes bearing red neck collars were observed: 1 on 30 April (collar code not read), and 1 on 10 to 15 May (crane EE30) which staged with approximately 200 other lesser sandhills. Observations have not been reported from nesting areas in Alaska.

During fall migration, individual red neck-collared cranes were observed in flocks of other lesser sandhills on the ECRD on 10 and 21 September 1980. Thus, up to 4 lesser sandhill cranes marked in California have been observed on the ECRD out of over 7,500 cranes observed close enough to determine marked birds in 1980. This information, plus similar population estimates of 20,000 lessers on the ECRD in fall and wintering in California (Lewis 1977), suggests these cranes represent a distinct Pacific Flyway population of lesser sandhill cranes.

Table 1. Sandhill crane age ratio counts during fall on the ECRD.

Interval	No. cranes	No. juveniles	% juveniles
1979			
24 Aug - 7 Sep	595	39	6.5
8-22 Sep	479	31	6.5
23 Sep - 7 Oct	518	34	6.6
Total	1,592	104	6.5
1980			
24 Aug - 7 Sep	870	39	4.5
8-22 Sep	1,003	82	8.2
23 Sep - 7 Oct	235	32	13.6
Total	2,108	153	7.2

Age Ratios

Fall counts of young of the year are a means of measuring annual productivity of lesser sandhill crane populations. Age ratio counts from the study area in 1979 and 1980 are given in Table 1. Fall staging periods were divided into equal thirds and age ratios were calculated for each third. Differences in percent juveniles between periods in 1979 were insignificant (Student-Newman-Keuls test, $P > 0.05$, Zar 1974), but percent juveniles increased significantly ($P \leq 0.05$) in 1980 over the staging period. The 1980 pattern reflects age distributions often seen among migrating geese (Cooch 1958) in which adults with young tend to migrate later than nonbreeders. Recruitment levels have been approximately 7% in both years. This figure is lower than Canadian (*G. c. rowani*) and lesser sandhill crane age ratios (11.6%) observed in the Central Flyway (Buller 1979). Either productivity in this population is inherently lower than the Central Flyway population, or 1979 and 1980 represented particularly poor years of production. Better assessment of productivity might be obtained through larger sample sizes if monitoring of age ratios of lesser sandhill cranes were initiated in California as cranes arrive on the wintering grounds.

Among 46 sandhill cranes examined from hunters' bags on the ECRD in 1979, 10 were juveniles, providing a sample age ratio of 21.7% young.

Compared to the 7% young consistently observed in staging flocks throughout 1979 (Table 1), this higher percentage in the harvest may indicate a greater susceptibility of juvenile cranes than of adults to hunting pressure. Hunter harvests of cranes in portions of Alaska supporting Pacific Flyway stocks have ranged from 300 to 500 birds annually over the past 10 years (Timm 1970-1980). Sandhill cranes are not presently hunted in other states or provinces of the Pacific Flyway.

Counts of family sizes were taken whenever distinct family units could be discerned in staging crane flocks. There was an average of 1.2 young per family in 84 families observed in fall of both years. Broods of 1 or 2 chicks were common and one 3-chick brood was observed in 1980.

Food Habits

Food items found in the gullet (esophagus and proventriculus) of birds are generally better indicators of food preferences than are gizzard contents, due to differing breakdown rates of soft and hard foods in the gizzard (Swanson and Bartonek 1970). Most food items could be identified in the gizzards of the cranes I examined, however, and the number of gizzards containing food was larger, so they are also included in this discussion. As shown by both gullet and gizzard contents, the predominant food of most sandhill cranes staging during the fall was arrow-grass, *Triglochin palustris* (Table 2). *Triglochin palustris* grows in a variety of situations but is most abundant in moist, mossy substrates with light sedge, grass, and shrub cover. It grows in wetlands over much of Alaska (Hulten 1974) and is also consumed on the breeding grounds (C. M. Boise, pers. comm.). Cranes probe at the base of the plant to locate the fleshy bulb. The entire plant is then uprooted and the stem is usually snipped off with the bill before the bulb is swallowed.

Table 2. Food items occurring in 32 gullets and 74 gizzards of sandhill cranes collected during fall of 1979 and 1980 on the ECRD, Alaska.

	Gullets			Gizzards	
Food items	% frequency of occurrence	Aggregate %	% of total dry weight	% frequency of occurrence	Aggregate %
Plant					
Triglochin palustris	87.5	86.4	93.2	95.9	83.0
Unidentified vegetation	9.4	tr[a]	tr	18.9	10.4
Equisetum spp.	3.1	tr	tr	4.1	tr
Moss[b]	3.1	tr	tr	22.1	tr
Carex spp.[b]	6.3	tr	tr	2.7	1.5
Potentilla egedii[b]	6.3	tr	tr	--	--
Drosera rotundifolia[b]	--	--	--	1.4	tr
Animal					
Gastropoda					
Snails (Lymnaeidae)	21.9	5.5	2.0	6.8	0.9
Insecta					
Cranefly (Tipulidae) adults	21.9	5.7	0.6	28.6	2.6
Cranefly (Tipulidae) larvae	6.3	tr	2.1	--	--
Beetles (Carabidae)	3.1	tr	tr	--	--
Dragonfly (Odonata) adults	--	--	--	1.4	tr
Unidentified insects	3.1	tr	tr	10.4	tr
Arachnida					
Spiders (Lycosidae)	3.1	tr	tr	1.4	tr
Hirudinae					
Leeches (Hirudinidae)	--	--	--	1.4	--

[a] tr = trace amount.

[b] Probably taken incidentally with other foods.

Table 3. Chemical composition (%) of whole *Triglochin palustris* bulbs on a dry weight basis.

Component	% of whole bulbs
Ash	5.3
Crude fat	0.02
Crude protein	14.8
TNC (total nonstructural carbohydrates)	35.6
P	0.39
K	1.70
Ca	0.60
Mg	0.17

Many gullets of cranes examined from the ECRD were filled with little except the bulbs of *T. palustris*, indicating cranes must actively seek out this food source and are adept at extracting the bulbs. Other food items of importance included snails and larval and adult craneflies, all of which occasionally appeared alone in gullet samples but most often were mixed in with *Triglochin* bulbs.

Oven-dried samples of *T. palustris* bulbs were analyzed for nutrient content by the University of Alaska Plant and Soils Laboratory, Palmer, Alaska. Results of the analyses (Table 3) compare closely with *T. palustris* bulbs from James Bay, Ontario (Thomas and Prevett 1980). The bulbs are relatively high in nonstructural carbohydrates, providing ample energy and substrate for fat deposition. They are also high in protein, essential for the buildup of muscle tissue in preparation for migration. Overall, the bulbs seem to provide a high-quality and probably easily digested premigratory food for staging cranes.

Competition for this food resource on the ECRD may come from staging dusky Canada Geese (*Branta canadensis occidentalis*) and to a lesser extent brown bears (*Ursus arctos*), which also selectively feed on the bulbs in fall (pers. obs.). Both geese and cranes prefer open, brush-free sections of the Wet Meadow for feeding on *Triglochin* and, as shrub expansion continues, competition for food and feeding space will increase. Cranes were occasionally observed feeding on *T. palustris* bulbs in the Salt Grass Meadow and will probably resort to this habitat more in the future.

Spring foods, as indicated from 3 gizzard contents and observations at feeding sites, showed green plant shoots and insects, mostly beetles (Carabidae), provided the bulk of the early spring diet. Later, after the shoots of *T. palustris* and the orchid *Spiranthes romanzoffiana* emerged, cranes fed on the overwintered bulbs of these plants.

Habitat Use

Staging sandhill cranes utilized the Wet Meadow habitat much more than other available habitats (Fig. 1) and feeding occurred almost exclusively in this habitat. The predominant Wet Meadow ground cover was a thick layer of moss with occasional shallow ponds and many intersecting tidal sloughs. Feeding cranes most often chose moist, open sites intermediate between wet depressions filled with water and the drier slough levees.

Comparative analysis between vegetative plots taken systematically over the entire Wet Meadow, and plots taken at crane feeding sites, showed preferences for specific plant associations. Kolmogorov-Smirnov goodness of fit tests (Zar 1974) were used to compare frequency distribution of percent cover by species between plot types (Table 4). Plant species are arranged in order of selection preference (D-values) by cranes on feeding areas. Species occurring in crane feeding sites more often than expected from the systematically taken plots have higher positive values, and species found less frequently than expected in crane feeding sites have higher negative values. It might be expected that cranes would choose sites where *T. palustris*, their primary food, grows in abundance. Unfortunately, when not in flower *T. palustris* was so similar in appearance to small sedges that it was seldom identified within the 1-m^2 plots.

Cranes approaching feeding habitat from the air would very likely not be able to identify *T. palustris* at this altitude and thus must key in on other plant species that have substrate and moisture preferences similar to *T. palustris*. It appears from the analysis that cranes selected sites dominated by *Carex ramenskii* and tended to avoid areas dominated by another common sedge, *Carex lyngbyaei*. Certain grass species were found frequently at feeding sites and several moss species, particularly *Hypnum* spp., also characterized feeding areas. Shrubs such as alder and willow were generally avoided. Feeding habitat generally consisted of areas of saturated soils with little standing water, light vegetative cover, and very light shrub cover.

Movement to roost sites while staging in fall occurred during a 1- to 2-hour period around sunset. Cranes roosted in all 4 wetland habitat types, although Medium Shrub and Intertidal Mudflat habitats were most preferred (Table 5). Within the Medium Shrub habitat, cranes apparently chose several shallow lakes as roost sites, but while on the ground in this area they could not be

Table 4. Kolmogorov-Smirnov goodness of fit test results on vegetation plots.

Plant species	$D_\alpha = 0.05$	Plant species	$D_\alpha = 0.05$
Carex ramenskii	+0.814[a]	*Plantago maritima*	-0.054
Hypnum sp.	+0.538[a]	*Primula egaliksensis*	-0.064
Poa eminens	+0.258	*Ranunculus cymbalaria*	-0.081
Calamagrostis spp.	+0.247	*Rumex fenestratus*	-0.085
Mnium sp.	+0.239	*Euphrasia mollis*	-0.101
Sphagnum sp.	+0.234	*Eriophorum scheuchzeri*	-0.104
Agrostis spp.	+0.221	*Polytrichum* sp.	-0.106
Stellaria spp.	+0.168	*Epilobium adenocaulon*	-0.109
Dwarf *Salix* spp.	+0.167	*Ceratodon* sp.	-0.124
Potentilla palustris	+0.134	*Myrica gale*	-0.142
Carex mackenziei	+0.122	*Epilobium hornemanni/palustre*	-0.165
Deschampsia beringensis	+0.116	*Equisetum* spp.	-0.168
Juncus alpinus	+0.097	*Chrysanthemum arcticum*	-0.176
Triglochin maritima	+0.093	Upright *Salix* spp.	-0.179
Eleocharis kamtschatica	+0.059	*Alnus sinuata*	-0.192
Carex pluriflora	+0.021	*Parnassia palustris*	-0.210
Triglochin palustris	+0.021	*Carex lyngbyaei*	-0.247
Lomatogonium rotatum	-0.003	*Potentilla egedii*	-0.261
Deschampsia caespitosa	-0.025	*Spiranthes romanzoffiana*	-0.264[a]
Galium trifidum	-0.030	*Rhinanthus minor*	-0.318
Agrostis exarata	-0.031	Intertidal algae spp.	-0.320[a]
Peltigera sp.	-0.031		

[a] Indicates significant deviation from expected distribution based on systematically-distributed vegetative plots.

Table 5. Habitats used by roosting sandhill cranes during fall on the ECRD.

	Number of cranes (%)		
Roost habitat	Fall 1979	Fall 1980	Combined years
Medium Shrub	4,581 (38)	4,251 (62)	8,832 (47)
Wet Meadow	1,733 (15)	1,108 (16)	2,842 (15)
Salt Grass Meadow	1,584 (13)	345 (5)	1,929 (10)
Intertidal Mudflat	4,107 (34)	1,115 (17)	5,222 (28)
Total	12,005	6,820	18,825

seen from the observation tower. Chi-square analysis showed no significant ($P > 0.05$) change in roost site preference due to tidal stage or weather factors, but cranes seemed to avoid roosting on exposed Intertidal Mudflat or Salt Grass Meadow sites during stormy weather. During severe storms cranes were virtually grounded and were forced to roost in open, grassy meadows close to feeding areas in the Wet Meadow habitat.

The more open Salt Grass Meadow will probably increase in importance to staging cranes in the future as Wet Meadow habitat is diminished by shrub expansion resulting from uplift by the 1964 earthquake. The dense muddy and silty substrates in Salt Grass Meadow will make it more difficult for cranes to obtain food, but the Salt Grass Meadow is expanding in size each year and even now provides limited staging habitat for cranes. Most of the Salt Grass Meadow is covered with saltwater during high spring tides and would be very susceptible to oil pollution from nearby crude oil tanker traffic departing Port Valdez and crossing the Gulf of Alaska.

CONCLUSIONS

As suggested by the evidence provided, a distinct Pacific Flyway population of lesser sandhill cranes exists, all of which very likely migrate through the eastern Copper River Delta, Alaska, and winter in California. If a 7% recruitment level is inherent within this population, monitoring of hunting pressure and habitat availability would be required to maintain the population at its present, stable level. Food availability appears to be adequate at present for cranes staging on the ECRD but, as shrub expansion continues in the Wet Meadow, competition for *T. palustris* will increase among cranes and geese. If crane use of the Salt Grass Meadow increases in the future, the ECRD may be 1 area where marine oil pollution could directly affect crane habitat.

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GREATER SANDHILL CRANES OF BURNETT COUNTY, WISCONSIN

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Abstract: This paper discusses the biology of greater sandhill cranes (*Grus canadensis tabida*) in Burnett County, Wisconsin. The importance of Crex Meadows, Fish Lake, and Amsterdam Slough State Wildlife Management Areas to cranes is documented. Breeding chronology and success, recruitment, and nesting habitat are discussed. Data are presented on fall staging populations and roost selection at Crex Meadows and spring distribution of cranes marked during the staging period. The effect of backpack radio packages on breeding success of 3 marked cranes is also evaluated.

Our study of greater sandhill cranes in Burnett County, Wisconsin, was designed to examine the status of cranes at Crex Meadows, Fish Lake, and Amsterdam Slough State Wildlife Management Areas (SWMA's). Crex Meadows was also evaluated as a fall staging area for cranes breeding in northwestern Wisconsin. Data on migration routes, stopover areas, staging areas, and wintering habitat of cranes that stage at Crex Meadows were reported elsewhere (Crete and Toepfer 1978). Previous and concurrent research in central Minnesota by Johnson (1976) and in Wisconsin by Hamerstrom (1938), Walkinshaw (1949, 1973), Gluesing (1974), Howard (1977), Bennett (1978), and Melvin (1978) provided background information and influenced design and completion of our study.

STUDY AREA

Crex Meadows, Fish Lake, and Amsterdam Slough SWMA's contain a total of 18,310 ha and lie within the St. Croix River watershed in northwestern Wisconsin (Fig. 1). The Wisconsin period of glaciation was responsible for the topographical features and soil structure of this region. Crex Meadows is the lowest portion of an ancient lake, Glacial Lake Grantsburg, which once covered all of the study area and portions of eastern Minnesota. The elevation of the study area ranges from 260-320 m above mean sea level with lowland and ridge differences of $\leq$10 m.

The study area is part of an extensive sand plain with level to gently rolling ridges interrupted by peaty wetlands (McLaughlin 1932). The zeric soils of the area support big and little bluestem (*Andropogon* spp.), brush prairies, and oak savanna communities when maintained by fire. Uplands revert to northern pin oak (*Quercus ellipsoidalis*), poplar (*Populus* spp.), and jackpine (*Pinus banksiana*) in the absence of fires (Vogl 1964). Lowlands contain extensive sedge-grass meadows, cattail marshes, shallow ponds, and lakes.

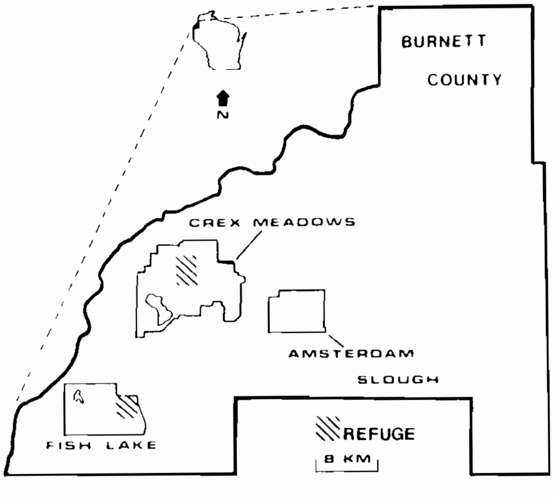

Fig. 1. Burnett County, Wisconsin, study areas.

The study area lies between the boreal forest and deciduous forest biomes and is therefore transitional. At Grantsburg, Wisconsin, the temperature range is -46.1 C to 42.4 C. The average 120-day frost-free summer has an annual average precipitation of 75.4 cm. February is the driest month with an average of 2.4 cm of precipitation and June is wettest, averaging 11.3 cm of rainfall (U.S. Dep. Agriculture 1941).

Artificial dikes and ditches on Crex Meadows and Fish Lake maintain water levels during most years. Fire breaks are maintained to facilitate upland management with fire. Posted refuges include 960 ha on Crex Meadows and 462 ha on Fish Lake. Cultivated food plots on these refuges and sharecropped land on Amsterdam Slough usually contained corn, rye, and buckwheat. Private cropland near the SWMA's contained corn, rye, oats, soybeans, snap beans, mixed pasture grasses, and alfalfa.

METHODS

Cranes were observed with 7X binoculars, a 15-60X spotting scope, and 1400X Questar Telescope. Telemetric study and marking methods were described in previous papers (Crete and Toepfer 1978, Toepfer and Crete 1979). The resident crane population on the study area was estimated during the nesting period (March-May), before the average hatch date of known nests. Crane territories were defined as those areas where any of the following existed: (1) cranes displayed agonistically toward other cranes (Voss 1977); (2) copulations were seen; or (3) where adults and colts were seen, even if previous sightings of cranes had not been recorded. Crane population estimates during the staging period (August-November) were based on counts at several roosts and feeding areas.

Nests were located by walking through portions of territories where unison calls were heard. Percent canopy coverage of nest site vegetation was recorded after 1 July during brood rearing (June-July) using a method developed by Daubenmire (1959) and modified by Howard (1977). The percentage of juveniles counted in staging period flocks of 10 or more cranes (Lewis 1974) was considered the recruitment success of cranes at Crex Meadows.

RESULTS AND DISCUSSION

Nesting

Cranes were 1st observed in the spring on 25 March 1976, 19 March 1977, and 1 April 1978. The average resident crane population was about 60 individuals in those years. At least 22 pairs of cranes were seen on territories in spring 1978. Nineteen pairs were seen on territories in 1977 and the highest number of nonbreeding cranes was seen that year (Table 1). Drought conditions caused low water levels in wetlands on the study area for most of 1976 and 1977.

Amsterdam Slough was the least important breeding area for cranes in the study area, but, based on the number of radio-tagged nonbreeders located on this area, use of the area by nonbreeding cranes was significant in 1978. Nonbreeders used sharecropped cornfields, rye strips, and wetlands unoccupied by territorial pairs.

The average size of 17 territories defended during nesting and brood rearing on Crex Meadows and Fish Lake was 126 ha (Table 2). Territories in southwestern Wisconsin averaged 38 ha (Bennett 1978) and those in Morrison County, Minnesota, averaged 158 ha (Johnson 1976).

The mean clutch size in 17 nests was 1.94 eggs. Twenty-one of 33 eggs hatched. The average hatch date for 11 nests was 20 May while the range was 11 May to 28 May (Table 3). Howard (1977) reported a 80.4% hatching success in central Wisconsin.

Table 1. Minimum number of sandhill cranes on the study area during spring, 1976-78.

State wildlife area	1976		1977		1978	
	In pairs	Non-breeders	In pairs	Non-breeders	In pairs	Non-breeders
Crex Meadows (10,700 ha)	14	7	13	26	14	19[a]
Fish Lake (5,200 ha)	5	4	6	3	8	--
Amsterdam Slough (2,410 ha)	1	--	--	--	--	--
Total cranes	40	11	38	29	44	19
	51		67		63	
Nonbreeders (%)	22		43		30	

[a] Minimum number of nonbreeding cranes on the study area including counts at Fish Lake and Amsterdam Slough SWMA's.

Table 2. Nest data and territory sizes of sandhill cranes in Burnett County, Wisconsin, 1976-78.

Year or category	Nest	Territory size (ha)	Nest size (cm)[a]	Nest materials[b]	Water depth (cm)
1976	1	159	120-100	1	18
	2	71	75- 68	2,3	18
	3	91	100-85	2,4,5	17
	4	168	--	2,4	30
	5	167	125-110	2,6	11
	6	131	91-75	2,6	6
1977	7	78	76-71	1,4	25
	8	151	91-71	7	41
	9	131	71-61	1	30
	10	167	91-91	1	0
	11	159	67-61	1	30
	12	127	--	1	23
	13	63	76-69	2	15
1978	14	167	98-83	1	8
	15	89	119-90	6,8	8
	16	133	77-70	3,8	8
	17	89	93-77	2,4,5	21
$\bar{x}$		126	91-79		18

[a] Longest diameter-shortest diameter.

[b] Nest material code: (1) *Carex rostrata*, (2) *Carex* spp., (3) *Chamaedaphne calyculata*, (4) *Typha latifolia*, (5) *Calamagrostis canadensis*, (6) *Salix* spp., (7) *Phragmites communis*, and (8) *Betula glandulosa*.

At least 1 colt was fledged from each of 11 of 17 (65%) nests. Two colts were fledged from each of 5 of 13 broods (38%). Cranes in central Minnesota also commonly fledge 2 colts. A crane radio-tagged at Crex Meadows nested in Morrison County, Minnesota, and fledged 2 colts for 3 years in succession. There appears to be a positive correlation between territory size and the number of pairs which successfully fledge 2 colts in the Great Lakes States. Colts were observed flying in late July and early August 65-75 days after the mean hatch date.

Annual recruitment of juveniles at Crex Meadows totaled 12.2% in 1976 and 15.2% in 1977. Recruitment was also estimated at Jasper-Pulaski area during late October 1976 and early November 1977 (Table 4).

Nesting Habitat

A variety of habitats were selected by cranes for nesting sites within wetlands. Two nests were found in bog communities dominated by leatherleaf (*Chamaedaphne calyculata*), *Sphagnum* spp., and bog birch (*Betula glandulosa*). One nest was found in a monotypic stand of *Phragmites* and 4 were in stands of beaked sedge (*Carex rostrata*). Ten nests were in mixed communities of sedges (*Carex* spp.), cattail (*Typha latifolia*), and bluejoint grass (*Calamagrostis canadensis*). Beaked

Table 3. Clutch size and success of sandhill cranes nesting at Crex Meadows and Fish Lake SWMA's.

	Year(s)			
Clutch size and nesting success	1976	1977	1978	1976-78
Number of nests	6	7	4	17
Eggs laid	11	14	8	33
Average clutch size	1.83	2.00	2.00	1.94
Eggs hatched	5	10	6	21
Hatching success (%)	45.4	71.4	75.0	63.6
Nest fledging success (%)	50.0	71.4	75.0	64.7
Mean May hatch date	20	18	26	20
Sample size	(N = 4)	(N = 5)	(N = 2)	(N = 1)

sedge, the dominant plant found around nests, was also the dominant material used by cranes to construct nests (Table 2).

Trapping and Marking Studies

Measurements of 24 cranes showed that all were *tabida* subspecies. Habitat of cranes radio-tagged at Crex Meadows was determined in the spring 1978 nesting period. Figure 2 shows known breeding areas in northwestern Wisconsin and east-central Minnesota and the general area where radio-tagged cranes established territories or flocked as nonbreeding cohorts in spring 1978.

Three adult radio-tagged cranes nested and layed fertile eggs in 1978. One nest was destroyed by avian predators; the other 2 pairs involved were successful in hatching and fledging colts. A 4th radio-tagged adult was found dead with its bill caught in the plastic neck collar attached the previous fall. The carcass contained an egg in the oviduct.

Staging Period Populations

Crex Meadows is the major staging area for cranes in northwestern Wisconsin and east-central Minnesota. The crane breeding area in Morrison County, Minnesota, studied by Johnson (1976) is a crane staging area until waterfowl season opens. This area has the potential to be a major crane sanctuary throughout fall if a refuge area is established that satisfies crane feeding, loafing, and roosting needs.

Table 4. Percentage of juvenile sandhill cranes in flocks at Crex Meadows (CM) and Jasper-Pulaski (JP) SWMA's, 1976-77.

Year	Area	Flocks counted	Birds counted	Average flock size	Percent juveniles
1976	CM	9	469	52	12.2
	JP	5	525	105	13.0
1977	CM	33	1,366	41	15.2
	JP	47	4,861	103	10.3
1976-77	CM	42	1,835	43	14.4
	JP	53	5,386	102	10.5

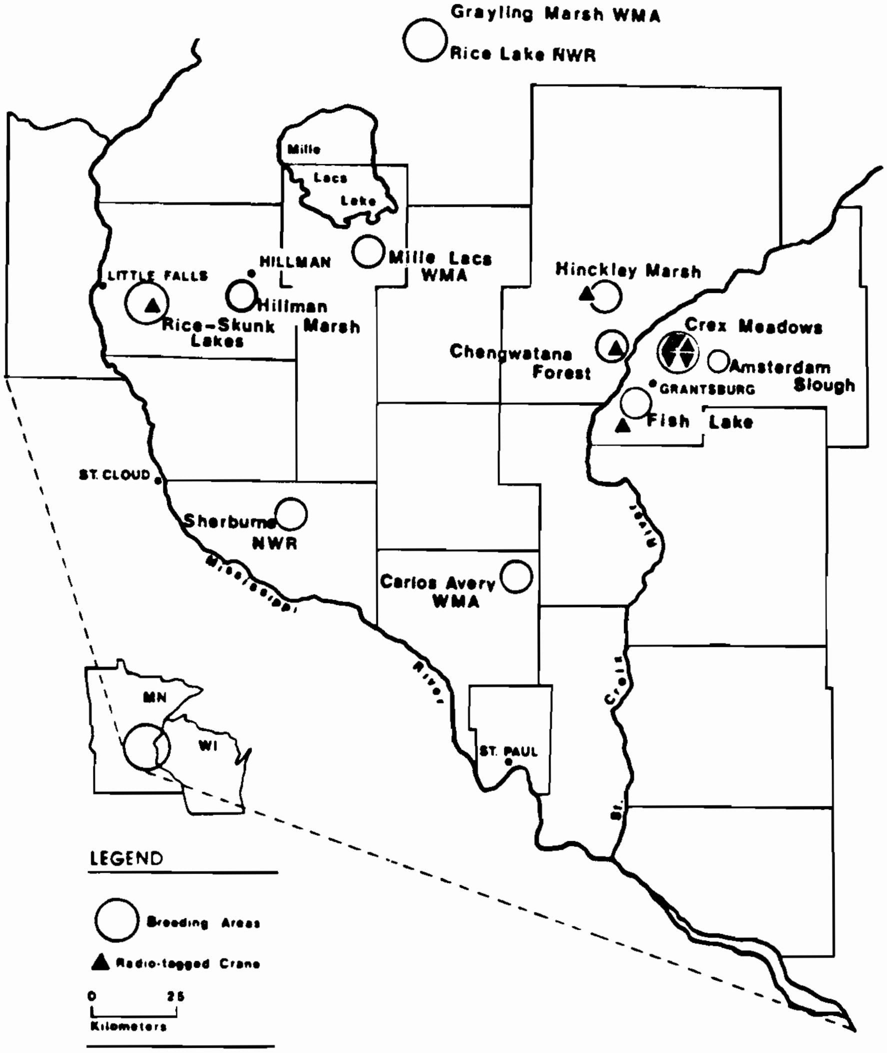

Fig. 2. Spring 1978 distribution of radio-tagged sandhill cranes marked at Crex Meadows during 1976-77.

Cranes were not seen on Amsterdam Slough and Fish Lake SWMA's during fall 1976 and 1977 staging periods. A refuge area was established on Fish Lake area in 1978 and cranes were seen there on sharecropped fields that fall. The refuge area had been open to duck hunting before 1978.

Crane numbers at roost and loafing areas increased in late August on Crex Meadows SWMA. Peak numbers of cranes were at least 179 and 181 individuals on this area in October 1976 and in November 1977, respectively (Fig. 3). R. Anderson (pers. comm.) reported that at least 300 cranes were counted on Crex Meadows during fall 1978.

Six roosts on Crex Meadows SWMA were used by most cranes during the brood rearing and staging periods. Roost selection by cranes was influenced by human disturbance during waterfowl hunting seasons in October and by surface water availability. Roosts on Crex Meadows refuge were extensively used by cranes during the waterfowl hunting season. During the staging periods, crane roosts were not found outside of the Crex Meadows area.

Information obtained on movements of radio-tagged cranes during migtation and on wintering areas was presented at the 1978 crane workshop (Toepfer and Crete 1979). All cranes followed in that study migrated to Florida via Jasper Pulaski (J-P) Fish and Wildlife area in Indiana.

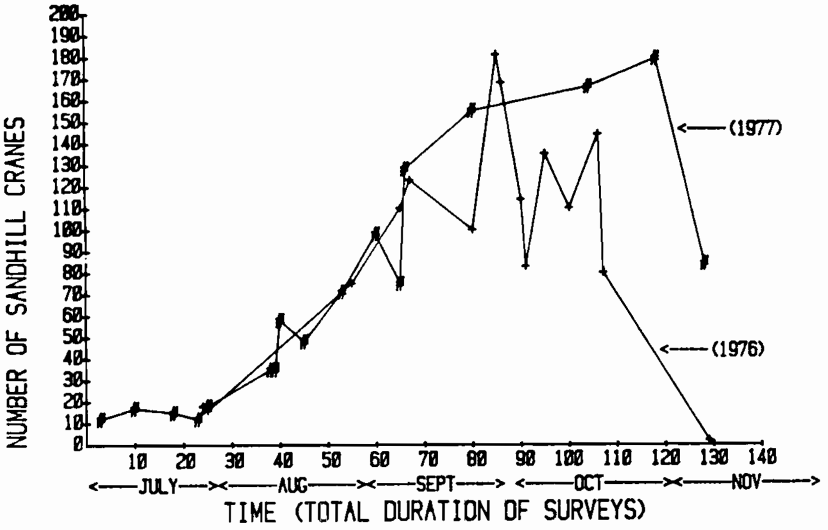

Fig. 3. Sandhill crane counts at Crex Meadows during staging periods in 1976 and 1977.

All cranes departed Crex Meadows by 19 November 1976 and 17 November 1977. Marshes were frozen and snow-covered by that time, but safe feeding, loafing, and roosting areas were available throughout the staging period. The absence of open water for night roosting appears to be the limiting factor forcing cranes to migrate from the study area in November. Migration occurred within 2 days after cranes were forced to roost in frozen marshes in November. At other crane breeding and staging areas in Minnesota and central Wisconsin, cranes depart nonrefuge staging areas following human disturbances during waterfowl hunting seasons in early October (Johnson 1976, Bennett and Nauman 1978, Crete and Toepfer 1978).

Management

Management practices by the Wisconsin Department of Natural Resources on public lands which benefit cranes in Burnett County include (1) water control in wetlands, (2) prescribed burning of uplands and wetlands, (3) restricted use of wildlife refuges, and (4) cultivation of wildlife food plots (or sharecropping). These practices maintain native brush-prairie-wetland habitats, isolation, and supplemental food sources for wildlife.

Migration of cranes from Crex Meadows in November reduces the probability of cranes being illegally shot during waterfowl hunting seasons in central Wisconsin and other states while the birds are en route to Florida. The refuge area on Crex Meadows attracts cranes and provides safe feeding-loafing-and-roosting areas for staging birds throughout the waterfowl hunting season in Wisconsin.

Cranes from Crex Meadows SWMA arrive at J-P in late November after the October peak crane population estimates are recorded there. Establishing crane sanctuaries similar to Crex Meadows refuge in central Wisconsin and Minnesota could reduce much of the stress of overcrowding now evident at J-P.

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THE PACIFIC COAST POPULATION OF LESSER SANDHILL CRANES IN THE CONTIGUOUS UNITED STATES

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Abstract: A majority of the lesser sandhill cranes (*Grus canadensis canadensis*) migrate through the Great Plains states to winter in west Texas, eastern New Mexico, and Mexico. However, about 25,000 lessers migrate to the Central Valley of California. Most of these cranes enter the western contiguous United States through the Okanogan Valley, in southeast British Columbia, and migrate south through eastern Washington and Oregon, and northeastern California. Major wintering areas are near Merced, Merced County; Lodi, San Joaquin County; Modesto, Stanislaus County; Goose Lake, Kern County; and Carrizo Plains, San Luis Obispo County, California. About 1,400 lessers migrate through western Washington and Oregon to a wintering area near Red Bluff, Tehama County, California. This wintering group does not intermix with cranes that migrate through eastern Washington and Oregon. The same migration routes are used in the spring, except for a minor eastward shift in southeast Oregon. Few lesser sandhill cranes are seen near Burns, Harney County, Oregon, in the fall, but in the spring this region is an important congregation area. Virtually the entire Pacific Coast population spends time in the Malheur-Harney Lakes Basin before continuing their northward migration.

Most lesser sandhill cranes migrate from their northern nesting areas through the shortgrass prairie states to winter in west Texas, eastern New Mexico, and Mexico. However, about 25,000 lessers do not use this route but instead migrate through western Canada and the Pacific Coast states to the California Central Valley. This report describes the historical and present migration routes and winter areas of the Pacific Coast population of lesser sandhill cranes in the contiguous United States.

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HISTORIC DISTRIBUTION

Lesser sandhill cranes have an extended history in the Pacific states. Fossil remains have been recovered from Pleistocene deposits in California including specimens collected from Rancho La Brae, Los Angeles County (Miller 1912), and McKittrick, Kern County (Miller 1925). Howard (1929) reported lesser sandhill crane remains from Indian kitchen middens in the Emeryville shell-mound between Oakland and Berkeley, Alameda County, with an estimated age of 1,000 to 5,000 years. Excavations from 2 large shell heaps on the southwestern shores of Lake Buena Vista, Kern County, also contained 2 bones of the subspecies (DeMay 1942).

These early reports indicate lesser sandhill cranes wintered and migrated in the Pacific Flyway long before recorded history, and they have continued to do so.

Historically, the subspecies extended south to San Diego, San Diego County (Bryant 1889). Willett (1912) considered cranes commonly reported along the southern California coast as the greater (*G. c. tabida*) subspecies. However, based on the present California distribution of the 2 subspecies, these birds were more likely lessers. Willett observed cranes flying over Los Angeles and in grainfields near Pasadena, Orange County. Northward, along the coast, the subspecies was considered only a transient in the San Francisco Bay, San Mateo County, region by the early 1920's, but Grinnell and Wythe (1927) stated they had been more common in former years.

Little historical information is available describing the migration routes. Jewett and Gabrielson (1929) reported 3 large flocks of cranes near Portland, in Columbia County, Oregon, between 1 October and 1 December 1902. These birds were believed to be of the greater subspecies, but in recent years most cranes that migrate through the Portland area have been identified as lessers. It was not until 29 October 1953 that subspecific identification was determined. A badly injured crane was found on Sauvie Island, Columbia County, which was identified by Jewett (1954) as a lesser. At that time there was only 1 study skin with full data from west of the Cascade Range.

East of Oregon's Cascade Mountains, Willett (1919) reported the subspecies as common on fields between Malheur Lake and Burns, Harney County, in late April 1918. In eastern Washington, Dice (1918) saw several large migrating flocks near Walla Walla, Walla Walla County, on 14 April 1908.

These birds were flying very high. Farther north, Munro (1919) observed a flock of 57 migrating north of Okonagan Lake, British Columbia, on 20 May 1915. He also reported large flocks rarely stopped in the Okonagan Valley in spring, but sometimes did in the fall. Individuals of both the greater and lesser subspecies were forced down during a violent windstorm on 4 October 1917.

PRESENT DISTRIBUTION

Fall Migration Routes

The Pacific Coast population of lesser sandhill cranes enter the contiguous United States along 2 migration routes (Fig. 1). For the sake of clarity we refer to the 2 routes as the western and eastern routes.

Eastern segment.--A majority of the Pacific Coast cranes (20,000 to 23,000) enter Washington from the Okanogan Valley, British Columbia. Residents near Okanogan, Okanogan County, Washington, report migrating cranes in spring and fall. On 1 October 1978, 1,200 cranes were present on the Colville Indian Reservation, Okanogan County, Washington (Rogers 1979). South of this area a major use area is located near St. Andrews, Douglas County, Washington. On 29 September 1978 an estimated 950 were seen there (Rogers 1979). Other areas where lessers are regularly seen include Potholes Reservoir and Banks Lake, both in Grant County, Washington. Over 1,000 were at Banks Lake on 14 October 1967 (Rogers 1968), and several large flocks were seen on 23-24 September 1972 (Rogers 1973). Numerous observations have also been recorded for Lincoln County, especially near Sprague (R. C. Friesz, pers. comm.). Near the Washington-Oregon border, 70 were seen on McNary National Wildlife Refuge (NWR), Walla Walla County, Washington, on 30 September 1964 (Rogers 1965), and the subspecies was seen flying over in late September and early October 1968 (Rogers 1969). Several other records also exist from Walla Walla and Benton Counties (R. C. Friesz, pers. comm.).

After leaving Washington, the population's eastern segment migrates over Cold Springs NWR and Umapine, Umatilla County, areas in Oregon. They continue south through Grant County to about 20 km north of Burns, where they change to a southwesterly heading. The migration route continues to the vicinity of Warner Valley and Lakeview, in Lake County, Oregon. Lessers leave these 2 areas in a southerly direction, leaving Oregon south of Adel and Goose Lake, in Lake County.

Lesser sandhill cranes leaving southeast Oregon pass over Goose Lake and Surprise Valley, both in Modoc County, California, and proceed south to Honey Lake, Lassen County, California. From Honey Lake they cross the Sierra Nevada Range and enter California's Central Valley in the vicinity of Merced, Merced County. Approximately 100 were seen migrating over the range from the east on 1 October 1969 (Baldridge et al. 1970) and 22 were seen about 10 km northeast of Auburn, Placer County, on 9 December 1973 (Stallcup and Greenburg 1974).

Western segment.--Lessers that use the western route enter Washington along the Pacific Coast south of Vancouver, British Columbia. Several fall records exist for Bellingham, Whatcom County; Everett, Snohomish County; and Skagit Flat, Skagit County. Occasionally cranes are seen farther west. On 4 September 1975, 25 flew over Cape Flattery, Challam County, Washington, on the northwest tip of the Olympic Peninsula (Crowell and Nehls 1976) and several have been seen in recent years near Astoria, Clatsop County, Oregon (D. Anderson, pers. comm.). These birds apparently migrate south from Vancouver Island, British Columbia, where several crane observations have been reported. From northwest Washington they migrate south to their major concentration area on Sauvie Island, Oregon, but regularly feed nearby at Ridgefield NWR, Clark County, Washington.

Sauvie Island, Oregon, is occupied by cranes from late September through November, before they continue south over the Willamette Valley. Often the migration is rapid. More than 1,000 were seen flying south over the Valley on 8 and 9 November 1969 (Crowell and Nehls 1970). In southwestern Oregon, the subspecies is considered a fairly regular migrant over Medford, Jackson County (Browning 1975), and they enter California, primarily east of Siskiyou Summit, Jackson County, southeast of Medford.

From the Oregon-California border, cranes migrate to Meiss Lake, Siskiyou County, California, and spend 3 to 4 weeks beginning in mid-October (McLoud 1954), before continuing south to their wintering area near Red Bluff, Tehama County, California.

Wintering Distribution

All known wintering areas were examined in 1969-70 and 1970-71. The wintering distribution for the Pacific Coast population is within the California Central Valley, and is divided into 2 separate areas (Fig. 2). A small group of about 1,400 birds winter east of Red Bluff. These birds apparently loaf and roost near the Sacramento River north of Red Bluff.

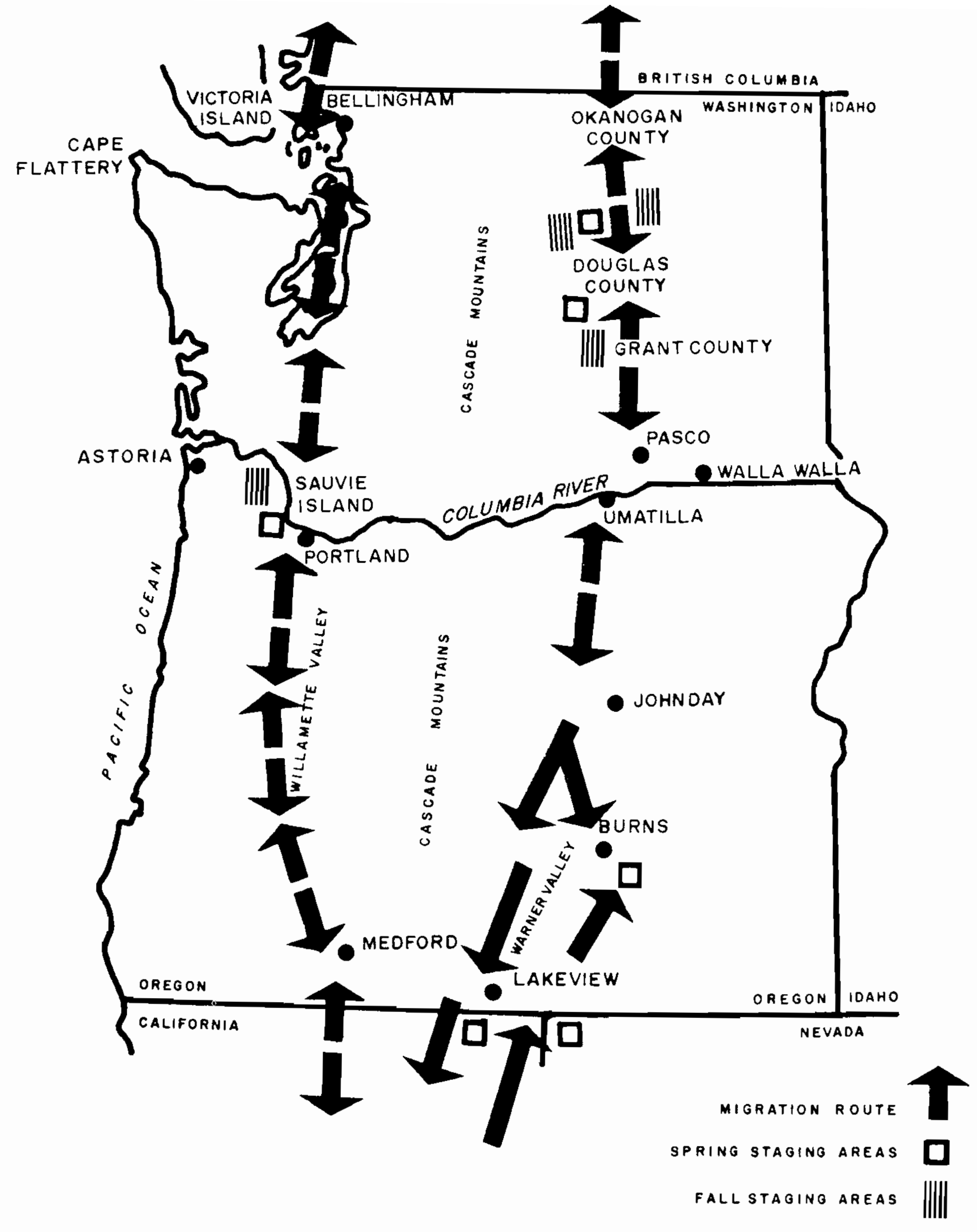

Fig. 1. Migration routes of Pacific Coast population of lesser sandhill cranes

An estimated 20,000 to 23,000 lessers winter from north of Lodi, near Thornton, San Joaquin County, California, southeast to the Carrizo Plains, east and south of Simmler, San Luis Obispo County, California. The majority winter near or on Merced and San Luis NWR's, Merced County, California. Few lessers have been seen between Red Bluff and Thornton, and apparently there is no interchange between the 2 wintering groups.

After entering the Central Valley in the fall most lesser sandhill cranes concentrate near Merced, then disperse northwest and southeast after spending 3 to 4 weeks in the Merced area.

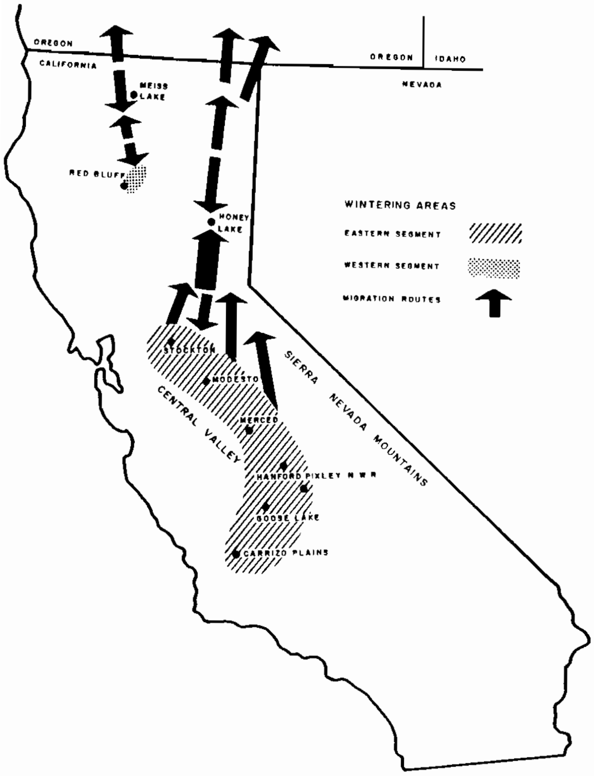

Fig. 2. Migration routes and wintering areas for the Pacific Coast population of lesser sandhill cranes.

Table 1. Peak numbers of lesser sandhill cranes at Merced NWR (1951-1978).

Year	Total estimated number	Year	Total estimated number
1951	3,000	1965	4,000
1952	1,500	1966	6,500
1953	2,000	1967	6,000
1954	5,000	1968	2,500
1955	5,000	1969	5,950
1956	50,000[a]	1970	1,460
1957	30,000[b]	1971	1,500
1958	21,500	1972	750
1959	15,000	1973	2,000
1960	15,000	1974	10,000
1961	9,000	1975	10,000
1962	21,000	1976	5,000
1963	15,000	1977	5,250
1964	9,000	1978	8,000

[a] This was thought to be an overestimate.

[b] Probably an overestimate.

Near Thornton, 828 lessers were counted on 14 December 1969. After this date a substantial increase was recorded. By late December over 2,000 were there; an estimated 4,100 were present on 7 January 1970. In Stanislaus County, California, the subspecies winters about 13 to 16 km west of Modesto on the Faith and Mape's Ranches at the confluence of the Tuolumne and San Joaquin Rivers. In 1969, lesser numbers fluctuated through mid-November, but stabilized in December. The peak number was on 4 November (2,100 individuals) when cranes were decreasing in Merced County. Merced County is the most important wintering area. Estimated peak numbers from U.S. Fish and Wildlife Service files are presented in Table 1.

On 23 November 1969, 324 lessers were using Melga Reservoir, 19 km south of Hanford, Kings County, California. By December their numbers had dropped to 4, and none was recorded on 26 January 1970. In Tulare County, California, 8 lessers were observed on Pixley NWR on 22 November 1969 for the only record on that refuge. However, southwest of this locality at Goose Lake, about 18 km west and 6 km south of Wasco, Kern County, California, cranes winter in large numbers. On 21 November 1969, 232 were using the area, increasing to 415 on 16 December and 628 cranes on 26 January 1970. West of Goose Lake large numbers of lessers also winter at the Carrizo Plains. In December 1966 an estimated 10,000 to 14,000 were present (McCaskie 1967), but normally the peak is between 2,000, and 3,000 individuals. In 1969-70, 3 counts were made--1,011 were counted on 24 November; 1,439 on 17 December; and 2,763 on 25 January 1970.

Along with those wintering in the California Central Valley a few winter in the Imperial Valley, Imperial County, California. Four were recorded 11 km southeast of Brawley in January 1971 and 1 was seen near Blythe, Riverside County, California, on 31 January 1976.

Occasionally, cranes are seen away from major wintering localities. These are mostly single individuals, but on 21 February 1964, 1,000+ were recorded near San Lucas, Monterey County, California (Chase and Paxton 1964).

The major Central Valley wintering areas have been used consistently since 1969. Information available from the early 1900's indicates that these wintering sites have been used for a much longer period.

Spring Migration Routes

Eastern segment.--The eastern segment leaves the Central Valley in a broad front from Merced north to near Lodi. Therefore, cranes occur at scattered localities in northeast California, and south-central and southeast Oregon. Regular stopping points in California include Big Valley, Modoc County, Surprise Valley, and Goose Lake. In Oregon, they move through the region from Sycan Marsh and Sprague River Valley, both in Lake County, east to Lakeview and Warner Valley. From these areas cranes migrate northwest to their major spring staging area in the Malheur-Harney Lakes Basin near Burns. Virtually the entire eastern segment of the population spends time in the Basin feeding in flooded native meadows. Normally, about 6,000 cranes are present during the population peak. However, when inclement weather persists in the Blue Mountains, north of Burns, the departure is delayed and up to 14,000 may be present. Migration progresses rapidly through eastern Oregon after cranes leave Harney County. From Burns they continue north along the same migration route used in the fall.

Stopping points in Oregon are different in the spring because of the prevalence of flooded native meadows which are lacking in the fall. Concentrations have been seen near Silvies and Fox, both in Grant County, Oregon. Occasionally, they occur east of the major migration route near LaGrande, Union County, Oregon (D. Kerley and S. Croghan, pers. comm.).

Yocum and Hansen (1960) indicated cranes stopped to rest in large numbers in 2 areas of eastern Washington. One area was in southeast Lincoln County, in the Ringwood Lake area, and the other was in Douglas County, along the western rim of Grand Coulee. Before flooding of Grand Coulee, lessers used the region near Steamboat Rock as a resting area and on 28 March 1951, over 1,000 cranes were seen near Devil's Lake, north of Steamboat Rock. Cranes left Washington by flying up the Okanogan River Valley where a flock of 30 was seen flying north near Oroville, Okanogan County, Washington, 19 April 1950. Other cranes apparently left the state by flying north up the Columbia River Valley. Birds that have recently been recorded near Turnbull NWR, Spokane County, could be using this route.

Western segment.--The western segment of the population's spring migration route is similar to that used in the fall.

Extralimital Records

Several spring records exist for western Idaho. An immature female was collected 2.4 km south-southeast of Genesee, Nez Perce County (Jollie 1955). The largest number recorded was 500 in southwest Idaho on 19 March 1978, and 350 along the Payette River in west-central Idaho in April 1978 (Rogers 1978). These birds probably migrate northwest toward Turnbull NWR, Washington.

Few records exist from western Nevada and east of the Sierra Nevada in California. One was collected at Ash Meadows, Nevada, on 10 March 1891 (Fisher 1893). Linsdale (1936) considered lessers transients through western Nevada, and Alcorn (1946) reported them as strictly migrants occurring usually in March and April in the Lahontan Valley, in Churchill County, Nevada.

One individual was present at Deep Springs, Inyo County, California, from late November 1964 through 11 March 1965 (McCaskie and Pugh 1965) and between 2 and 6 were seen at the same location between 9 and 17 October 1970 (McCaskie 1971).

Because a few lessers normally winter near Brawley, birds seen east of the Sierra Nevada could be migrating to that region. Five were seen about 85 km north of Brawley, at the north shore of Salton Sea, Imperial County, California, on 25 October 1977 (McCaskie 1978), and several other records also exist for that area.

CONCLUSIONS

Lesser sandhill cranes have been present in the Pacific Flyway since long before the arrival of Paleo-Indians. Fossil evidence indicates the subspecies was widespread in California during the Pleistocene. Today, lessers are found in many of the same regions that they were during the earlier epoch.

The future of the subspecies in the Pacific Flyway appears promising unless wintering habitat is eliminated and nesting areas are disturbed by energy development. With increasing numbers of humans in California, and oil development in probable Alaskan nesting regions, the population's status should be closely monitored. At the present time specific nesting areas are unknown. It is essential that nesting regions be delineated so the cranes can be protected from habitat degradation and disturbance. Fortunately, migration habitat appears adequate and secure for the future welfare of the subspecies in the Pacific Flyway.

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WORKSHOP RESOLUTIONS SUBMITTED TO PERSONS OR AGENCIES

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CANADIAN WILDLIFE SERVICE

Participants in the 1981 Crane Workshop convened 25-27 August at Grand Teton National Park wish to extend their congratulations and encouragement to the Canadian Wildlife Service for its innovative programs in the study and management of whooping cranes, particularly the issuance of eggs to the foster-parent experiment in Idaho and color-marking and radio-marking the prefledged whooping crane chicks at Wood Buffalo National Park. Thanks to the work of the Canadian Wildlife Service the future for the whooping crane looks brighter and other nations harboring endangered cranes have a model for research and international cooperation in conservation.

ENVIRONMENTAL AGENCY OF JAPAN

In view of the successful program in Canada and the USA concerning the color-marking of prefledged whooping cranes and the insight such a program has provided into the biology of this endangered species, participants of the 1981 Crane Workshop support the position of crane researchers in Japan. We request that the Environmental Agency of the Government of Japan grant permission for color-marking of prefledged red-crowned cranes in southeast Hokkaido. Individual recognition of cranes will provide valuable information about productivity and mortality as a factor of age, information from which conservation programs can be developed to better assure the survival of the treasured birds in Japan and on mainland Asia.

JAMES WATT, SECRETARY OF INTERIOR

Whereas: The marshes, lakes, and sloughs along the bay side of Matagorda Island, Texas, are critical wintering areas for the endangered whooping cranes and provide the best area for expansion of range by an increasing whooping crane population and have been designated as whooping crane critical habitat by the U.S. Fish and Wildlife Service and,

Whereas: greatly increased public use or commercial development on the lands adjacent to these wetlands would greatly reduce or eliminate their value as whooping crane habitat and reduce Matagorda Island's value to other endangered species such as the peregrine falcon and certain sea turtles and,

Whereas: the Texas Parks and Wildlife Department is more subject to political pressure from interests favoring increased public use or commercial development of Matagorda Island than is the U.S. Fish and Wildlife Service, and

Whereas: the former Air Force Bombing Range on Matagorda Island has been operated for several years as a part of the Aransas National Wildlife Refuge;

therefore be it resolved that the participants of the 1981 Crane Workshop convened at Grand Teton National Park 25-27 August 1981 wish to strongly oppose the transfer of the former United States Air Force Bombing Range on Matagorda Island, Texas, from control of the United States Fish and Wildlife Service, to the state of Texas.

NATIONAL AUDUBON SOCIETY

Participants in the 1981 Crane Workshop convened 25-27 August at Grand Teton National Park wish to extend their congratulations and encouragement to the National Audubon Society for their long-term support of research on the winter biology of whooping cranes at the Aransas National Wildlife Refuge.

PATUXENT WILDLIFE RESEARCH CENTER OF U.S. FISH AND WILDLIFE SERVICE

Participants in the 1981 Crane Workshop convened 25-27 August at Grand Teton National Park wish to extend their congratulations and encouragement to the Patuxent Wildlife Research Center of the U.S. Fish and Wildlife Service for advances in the management of the endangered whooping crane and Mississippi sandhill crane, a long-term and challenging captive propagation program that recently blossomed with (a) the fledging of wild whooping cranes at Grays Lake National Wildlife Refuge as a consequence of placing Patuxent-produced whooping crane eggs under wild sandhill cranes and (b) the successful release of 9 captive-reared Mississippi sandhill cranes with the relict population of their kind in Jackson County, Mississippi.

U.S. DEPARTMENT OF THE INTERIOR

Participants of the 1981 Crane Workshop convened at Grand Teton National Park 25-27 August 1981, wish to recommend that the United States Department of the Interior quantify the flows required to maintain crane habitat in the Big Bend of the Platte River and develop, in cooperation with appropriate states, a water-management program that will provide such flows.

U.S. FISH AND WILDLIFE SERVICE AND NATURE CONSERVANCY

Participants in the 1981 Crane Workshop convened 25-27 August at Grand Teton National Park wish to extend their congratulations and encouragement to the United States Fish and Wildlife Service and the Nature Conservancy in Mississippi for their grand achievements in protecting and improving the habitats of the endangered Mississippi sandhill cranes in Jackson County, Mississippi.

UNIVERSITY OF IDAHO

Participants in the 1981 Crane Workshop convened 25-27 August at Grand Teton National Park wish to extend their congratulations and encouragement to the University of Idaho for their excellent crane research and conservation in the experiment through which a self-sustaining population of migratory whooping cranes may soon be established in the Rocky Mountains. Drs. Elwood Bizeau and Rod Drewien are praised for their meritorious management of this long-term program that began at Grays Lake National Wildlife Refuge in 1969.