To be justifiable any wildlife study should strive to attain and describe new knowledge or refine existing understanding. Published results of field studies are often the products that conclude the study, though not always. But, as E.O. Wilson wrote in Consilience: The Unity of Knowledge, “One of the structures of the scientific ethos is that a discovery does not exist until it is safely reviewed and in print.” Putting knowledge to page requires effort and, frequently, the abandonment of one’s own ego. However, ego notwithstanding, this is not the only reason to publish research findings. Whether we are trying to improve the management of a hunted population or to restore an endangered one, we should want to elucidate what we have discovered. This collected wisdom is the science of wildlife management and it is what society depends on to progress up the ladder of understanding and resource preservation. Science as a discipline cares little what we think, and only slightly more about what we know. In reality science only fully accepts what we can prove, and we can consistently prove only what is true. The body of science is formed from layers of collaborative knowledge. Each of study, whether innovative or prosaic, dazzling or mundane, should become part of the body so others can draw upon it, as we have, to move understanding forward. The need to inform others of the truths we have found is perhaps our first responsibility to the natural resources we study.

A second responsibility is for us to account for the capital used to find the answers to the questions we posed. Put simply, we must justify the money we have spent. Most government agencies or granting entities have built-in reporting requirements, which minimally address this need. But we should strive to go beyond the minimum accounting responsibility and make our new knowledge available to the broadest audience possible. Using scarce conservation dollars also carries the responsibility to maximize the benefit through the publication of study results in rigorously reviewed journals.

Many of us were drawn to wildlife biology because of an interest in life beyond our own species. Whether we came to the profession through an enjoyment of the out-of-doors, or through an abiding concern for natural resource conservation, in the end we wanted to work with wild animals and, for those of us participating in these proceedings, those animals are cranes. Irrespective of whether we work with captive flocks or with wild populations there is a debt we owe to these animals we study.

Management efforts to reintroduce or enhance lost or depleted crane populations, anywhere in the world, would be impossible without prior study. If we took the shot in the dark approach to population restoration, success would be less assured, and the amount of endangered resources that would be lost in the process would be hard to justify. Prior study is needed to develop new techniques as well as to establish milestones by which we can mark progress or redirect efforts. Preliminary investigations may involve many of the recognized tools of scientific study, beginning with the application of the scientific method as part of the planning process. The field phase might entail capture, banding, color marking, and transmitter attachment: all these manipulations involving some degree of risk. Monitoring methods could include the use of radio telemetry, either conventional or satellite based. Data analysis would perhaps be based on global positioning systems and satellite imagery for habitat mapping. Analysis might also employ the latest statistical techniques. No matter how sophisticated the methods we are using, or whether we are using them to describe, sustain, or restore a population, in the end we are working with free-living cranes. Even with the protocols developed as a result of concern for the animal’s welfare, our research activities interfere in the life of the birds we study. It may take several hours for a crane to recover from the effects of capture and handling or to adjust to the unfamiliar weight of an aluminum leg band, color marker, or radio transmitter. Such effects may well be negligible and, in the long run, have no adverse impact on normal activities or survival. But, no matter how benevolent the intent or important the outcome, our actions are still intrusions. Even if we are simply observing the movements and behavior of unmarked cranes in a natural setting, we may be inadvertently influencing their activities by precluding an animal’s access to that location.

No matter how benign the method, recognizing that we are having an impact on the individuals we are sampling brings us to another obligation, compensation to the species in reparation for our impositions. A fundamental ethical tenet of our profession dictates that we respect the animals we study. A manifestation of this level of respect is to make certain that the projects we undertake, no matter how little risk they seem to involve, are necessary and worthwhile. We must be certain the information we collect will balance the interference our actions will cause. If the study is not going to produce new scientific truths, then it probably ought not to be undertaken in the first place. A properly designed project should bring new information to light that equalizes the impacts to the individuals studied. It is our ultimate obligation to make sure the knowledge gained is used to the benefit of the species. To do otherwise would be irresponsible and arrogant.
If we study cranes and interfere in their self-directed behaviors, we should be committed to making sure any interruptions and risks we have forced on them return value to their kind. We must repay the debt to the lives we have disrupted. The debt has not been completely fulfilled until we have shown others what we have derived from our research, so this additional knowledge can help to firm the foundation for the future.
SANDHILL CRANE MORTALITY DURING FALL MIGRATION STOPOVER IN NORTH-CENTRAL NEW MEXICO, FALL 2001

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Abstract: Seventy-three Rocky Mountain greater sandhill cranes died after being mired in mud at a traditional migration stopover site during a fall migration 2001. Drawdown of the Jemez Canyon Dam reservoir in New Mexico resulted in over 200 acres of deep saturated silt and clay into which sandhill cranes became entrapped. Harassment to discourage birds from landing in the area was implemented immediately and partially successful. Rescue efforts were delayed because of an inability to safely access the cranes in these conditions. After 9 days, the use of a specialized 20-horsepower motor mounted on a small aluminum boat was employed. Seventeen birds were rescued, and 14 were successfully treated and released. The rescue was a cooperative effort among Hawks Aloft, Inc., the Albuquerque Biological Park, the U.S. Army Corps of Engineers, and the U.S. Fish and Wildlife Service. Reservoir managers and wildlife management organizations are encouraged to proactively prepare for the potential for a similar event.

Key words: sandhill cranes, mortality, reservoir management, avian mortality, wildlife rescue, veterinary treatment

The Rocky Mountain population (RMP) of greater sandhill cranes (Grus canadensis) breeds in portions of Colorado, Idaho, Montana, Utah, and Wyoming and winters in Arizona, New Mexico, and northern Mexico (Drewien and Bizeau 1974; Drewien et al. 1987; Manes et al. 1992; Drewien et al. 1996; Drewien et al. 1999). Several locations along the Chama, Jemez, and Rio Grande rivers in New Mexico are used consistently as over-night roost sites during migration between the San Luis Valley, Colorado, stopover site and winter areas, particularly in fall (Fig. 1). The Jemez River and the upper end of Jemez Canyon Reservoir are most heavily used (> 50% of overnight roosting cranes) (Stahlecker 1992).

STUDY AREA AND BACKGROUND

Jemez Canyon Dam was built in 1953 and spans the Jemez River in Sandoval County, NM, approximately 2 miles upstream from its confluence with the Rio Grande. The dam, authorized for flood and sediment control, is located on lands of the Pueblo of Santa Ana, and is managed by the U.S. Army Corps of Engineers (Corps). The Corps began maintaining a small persistent pool to trap sediment within the reservoir basin in 1979, and in 1985 the pool was expanded to approximately 20,000 acre-ft. Through 1999, approximately 19,000 acre-ft of sediment had been trapped in the reservoir. The sediment pool storage agreement with the Interstate Stream Commission expired in December 2000 and was not renewed due to the increasing scarcity of available water and the fact that the Rio Grande is now in a sediment-starved condition. In October 2000, the pool was reduced from approximately 19,000 to 4,000 acre-feet of storage. In spring 2001, about 13,000 acre-feet of water were stored in the reservoir for the purpose of eventual release to the benefit of downstream endangered Rio Grande silvery minnows. The Corps planned to store the water over winter 2001-2002; however, they discovered that a bulkhead door of the dam outlet would not function properly in a major flood event. The pool was fully evacuated October 3 through October 27, 2001, to facilitate repair. The drawdown resulted in the exposure of approximately 200 acres of deep, saturated silt and clay at the downstream end of the reservoir.

METHODS AND RESULTS

On November 6, 2 cranes trapped in mud at the reservoir were reported to the Corps. The following day, the Corps observed 24 trapped cranes. Cranes became mired to their bellies immediately upon attempting to land on the surface, which from above appeared to be a very attractive shallow water roost site. Although other avian species sometimes landed in the mud, only cranes became trapped. Waterfowl were observed landing and immediately taking off again.

The Corps immediately instituted a variety of harassment techniques to discourage cranes from roosting in the hazardous area. Personnel fired crackers, whistling, and pyrotechnic shells, and a large World War II era searchlight played over the area during the two hours spanning sunset. However, over the next 10 days, additional birds occasionally wandered into the area in early mornings after roosting safely upstream. Deterrent activities were continued until November 30.

Many mired birds attempted to escape by dragging themselves along the surface with their half-folded wings. Most cranes were able to move short (up to 10 m) distances, but at least 10 successfully reached shore from as far as 180 m away. However, 9 of these birds were killed, or died and were scav-
engaged, by predators (primarily coyote). One bird that reached shore on November 8 was captured by hand, treated by a wildlife rehabilitator, and later released.

Numerous methods of rescue for trapped birds were investigated and rejected. Conditions were not suitable for either hovercraft or airboats, and a helicopter operation was deemed to be too dangerous. Only one bird was rescued from the shore. On November 15, the Corps acquired a modified outboard motor (Go-Devil, Baton Rouge, LA). The motor used was a 20-horsepower outboard motor with a propeller mounted on a 10-foot shaft which, when used with a small lightweight flat-bottom boat, moved through the saturated mud. The boat was unable to maneuver through the areas that had dried on the surface, in which some cranes were trapped.

Over the next several days, biologists from the Corps, Hawks Aloft, Inc. (a local NGO), and the U.S. Fish and Wildlife Service (Service) retrieved 16 live cranes from the mud using the boat. Some cranes had been mired in the mud for up to four days and remained alive. Immediately upon retrieval, cranes were wrapped in blankets for ease of handling and warmth, and caked mud was removed from their nares using warm water. Birds were then transported to a facility for medical treatment. A wildlife rehabilitator treated three birds; veterinary staff at the Albuquerque Biological Park treated the remainder in the following manner:

Upon arrival, a team of 3-5 veterinary staff cleaned the
caked mud encrusted the feathers of each crane with warm, running water and assessed its overall condition. This treatment took place in a heated indoor facility that reduced additional energy demands of highly stressed birds. The cranes that were known to have been mired for several days were in the poorest condition, and were clinically assessed as dehydrated, hypothermic and hypoglycemic. Several of the birds had significant contusions to their carpi from using their wings in a rowing motion in attempts to escape the mud. Most birds were too weak to stand after cleaning, and were bedded on grass hay in a heated indoor chamber until they regained the strength to stand. Initial medical treatments used included: 60 cc of water containing 10 cc of 50.0% dextrose for rehydration and a quick source of energy, given via orogastric tube; an injectable antibiotic (enrofloxacin at 5 mg/kg); injectable vitamin E at 5 mg/kg to help prevent capture myopathy; and dexamethasone at 0.5 mg/kg for stress and shock.

After 24 hrs, depending on response to initial treatment, most birds received via orogastric tube 60 cc of Vivonex Plus®, an elemental diet that is readily absorbed. Several birds required an additional cleaning to remove residual mud. In the afternoon, the birds received via orogastric tube 60 cc of Hills AD®, a commercial high calorie dietary supplement for small animals. With the exception of the antibiotics, the initial medical treatments were not repeated.

At 48 hours, many of the birds had still not shown any interest in eating on their own and once again they received 60 cc of the Hill’s diet in the morning. By afternoon, all the birds were showing some interest in eating and were not provided further supplemental feed.

Once birds began eating, they were moved from indoor housing in the zoo vet clinic to a more secluded location in the zoo clinic barn that provided access to a covered outdoor area. This appeared to calm birds and improved their food consumption. The last few rescued birds had been trapped for less than 24 hours. These birds did not require the emergency medical treatment of the more severely traumatized birds, and were simply cleaned up and placed in the barn. These birds began eating soon after arrival and were able to be released a few days later.

Three cranes died in captivity, 2 from probable respiratory failure after inhaling mud, and one from exertional myopathy. All birds that died had been trapped for over 24 hours, and 2 of these were treated by a wildlife rehabilitator rather than the veterinary staff. The 14 survivors were banded and released at Bosque del Apache National Wildlife Refuge and refuge staff assisted in monitoring their survival.

In all, 87 birds were trapped in the reservoir November 6-28. Seventeen were rescued, and 70 died on site. At least 9 cranes were successful in their attempt to reach the shore, but were either dead, or were killed by predators, and then scavenged. Three others died in captivity.

DISCUSSION AND MANAGEMENT RECOMMENDATIONS
A combination of climatic conditions, structural damage to the dam, and timing of decision-making resulted in a unique situation for which the managing agencies, were not prepared. The result was a mass mortality of sandhill cranes, and considerable cost in terms of time, resources, and unfavorable media exposure for the Corps. In 2001, the 3-year average of the RMP crane population indices was 18,683, and the estimated retrieved harvest of cranes was 898 (Sharp et al. 2002). The loss of 73 sandhill cranes by this event was an additional 8.1% to the estimated hunting mortality for RMP cranes. This was not biologically significant; however, it likely would have been without the sustained efforts of the agencies and their partners. The knowledge gained through these efforts can be used to avert or more efficiently manage such an event in the future.

The medical intensive care facilities and veterinary staff at the Albuquerque Biological Park contributed to the high survival rate of the rescued cranes. It is unlikely that the most dedicated and highly trained private wildlife rehabilitation facility would be able to provide the personnel, level of care, medications, and specialized diet necessary for a rescue operation of this type.

Following are primary management recommendations:

- Following a reservoir evacuation, fine-grained sediments in the depositional bed will require a significantly longer time to drain than coarse-grained and perhaps, the native bed material. Requisite hydrological and geotechnical analyses should be performed prior to evacuation.
- The slurry-like substrate that was lethal to cranes would also be so to other long-legged waders (e.g., herons), or water birds that must run to get aloft (e.g., swans). Be aware of local or migratory bird species and their seasonal movement schedules.
- Conventional water craft may not be sufficient for emergency response. Be familiar with optional craft and how and where to obtain them quickly.
- Have a monitoring scheme and rescue plan in place prior to and following an evacuation.
- Prompt removal and treatment of trapped birds is essential to recovery. In instances such as this, with high numbers of large birds, the rescued animal should be handled by qualified veterinary staff, with facilities for cleaning, treating, and isolating birds.

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LITERATURE CITED


Abstract: One hundred and fifteen Florida sandhill crane (Grus canadensis pratensis) chicks were captured in Osceola and Lake Counties, Florida in 1998 - 2000 and examined for evidence of disease. Evidence of Eimeria gruis and/or E. reichenowi infection was found in 52% of chicks examined. Ten chicks were positive for antibodies to St. Louis encephalitis virus and 1 of these chicks was also positive for antibodies to eastern equine encephalitis virus. Predation was the most commonly identified cause of mortality. An unidentified microfilaria, and an unknown protozoan were detected in blood smears from crane chicks. A number of other disease conditions were also encountered, including: ant bites, chigger infestations, helminth infections, bacterial infections, leg problems associated with capture, and a bill deformity.

Key words: eastern equine encephalitis, Eimeria, Florida, Grus canadensis pratensis, predation, sandhill crane, St. Louis encephalitis.

Many disease agents have been reported in sandhill cranes (Grus canadensis). Forrester and Spalding (2003) reported more than 40 disease agents in sandhill cranes in Florida. Antibodies to two arboviruses, eastern equine encephalitis (EEE) and St. Louis encephalitis (SLE), were also identified in cranes from Florida (Forrester and Spalding 2003). Avian pox was identified in Florida sandhill cranes (Simpson et al. 1975, Forrester and Spalding 2003). Suspected poisoning due to Fusarium mycotoxins from peanuts resulted in extensive sandhill crane mortality in Texas and New Mexico and was noted in migratory sandhill cranes in Florida (Forrester and Spalding 2003, Roffe et al. 1989, Windingstad et al. 1989), although, this disease has not been recognized as an acute cause of death in Florida sandhill cranes (Forrester and Spalding 2003). Trauma due to power line collisions and vehicle strikes also results in mortality (Forrester and Spalding 2003, Windingstad 1988).

In studies undertaken to identify causes of disease and mortality in prefledged sandhill crane chicks, predation has been identified as a major source of mortality (Littlefield and Linsteadt 1992, DesRoberts 1997, Ivey and Scheuering 1997, Nesbitt and Schwikert 1999). The most commonly identified predator in these studies is the coyote (Canis latrans). Other conditions identified that resulted in disease or mortality in sandhill crane chicks during these studies include tracheal worms (Syngamus trachea), an unidentified bacterial infection, drowning, and intraspecific aggression. The goal of this study was to identify disease conditions and causes of mortality in prefledged sandhill crane chicks in central Florida.

STUDY AREA

Sandhill crane chicks were captured in Osceola and Lake Counties of central Florida (Fig. 1). Five areas were used as primary study sites; Escape Ranch (27° 53’ N, 80° 57’ W), Hayman’s 711 Ranch (27° 50’ N, 80° 59’ W), Overstreet Rd. (27° 57’ N, 81° 12’ W), Gardner-Cobb Marsh (28° 2’ N, 81° 18’ W), and Pruitt Ranch (28° 44’ N, 81° 56’ W). Three areas were used as incidental study sites: Crescent J Ranch (28° 4’ N, 81° 3’ W), Disney Wilderness Preserve (28° 8’ N, 81° 26’ W), and Kissimmee Park Rd. (28° 14’ N, 81° 19’ W). Incidental study sites were visited only once or twice during this study, whereas primary study sites were visited multiple times per week during the years they were used. All areas had extensive improved cattle pastures with scattered shallow seasonal and semipermanent marshes. Intermixed around and through the middle of pastures were pine flatwoods, oak woodlands, and cypress domes of varying sizes. Cattle grazing was conducted on all primary study sites; sod harvest was conducted on some (Escape, Haymans, Overstreet); and secondary uses included hunting, fishing, and birdwatching. Two of 3 incidental sampling areas were primarily cattle ranches; the third (The Nature Conservancy’s Disney Wilderness Preserve) was being man-
aged for native ecosystems. Bishop (1988) conducted a
detailed review of land-use patterns and ecological traits of these
and other Osceola County sites.

Study areas were not used in all years of this study. In
1998 only Escape Ranch and Hayman’s 711 Ranch were sam-
ped. Overstreet Road, the Pruitt Ranch, and the Gardner-Cobb
Marsh were sampled in 1999 and 2000. The 3 incidental study
sites were only sampled in 2000.

METHODS

Primary study sites were surveyed thoroughly from a ve-
hicle 3 to 4 times weekly throughout the sandhill crane breed-
ing season. When chicks were encountered they were chased
by the observer on foot until they were captured by hand. Chick
captures were made throughout the day. During 1998, chicks
were not marked, and all captures were made on an opportu-
nistic basis. DNA obtained from red blood cells was used to
identify individuals (Jones 1998). In 1999 and 2000 all chicks
encountered were marked with a uniquely coded transponder
(Trovan Electronic Identification Systems, Trovan, Ltd., United
Kingdom). The transponders were inserted subcutaneously in
a dorsal location between the wings. To facilitate recapture of
specific individuals and recover carcasses, a subset of these
birds was also fitted with radio-transmitters (Advanced Telem-
etry Systems, Isanti, MN) as per Spalding et al. (2001). Chicks
were sampled approximately every 2 weeks. Captured birds
were held for up to 30 min before being released back to their

Fig. 1. Location of primary and incidental study sites of disease factors in Florida sandhill cranes in the
state of Florida.
parents or at the site of capture. All chick carcasses that were recovered were necropsied.

**Blood Sampling**

Approximately 1 ml of blood was drawn from the jugular vein using a 1 ml insulin syringe with a 27-gauge, 13 mm needle. Blood smears were made in the field immediately following blood collection. Blood smears were fixed with methanol, stained with Leucostat (Fisher Diagnostics, Pittsburgh, PA) or Giemsa (E. M. Science, Gibbstown, NJ), and examined with a compound microscope for blood parasites. The remainder of the blood was centrifuged and the serum was tested for evidence of infection by selected mosquito-borne viruses including SLE virus (Flaviviridae: Flavivirus) and EEE virus (Togaviridae: Alphavirus).

Serum samples obtained in 1998 and 1999 were frozen immediately after centrifugation of whole blood samples, held for up to 1 month, and then transferred to a -60°C freezer until submission for antibody testing to the Centers for Disease Control laboratory in Fort Collins, Colorado. Specific antibodies were detected using the plaque-reduction neutralization test (PRNT) (Beaty et al. 1995) using reference strains of SLE virus (TBH-28) and EEE virus (NJ/60). In 2000, serum samples for antibody testing were frozen immediately after centrifugation of whole blood samples and then submitted bi-weekly for analysis to the Florida Department of Health and Rehabilitative Services, Tampa Branch Laboratory, Virology Section. Sera were first screened using a hemagglutination-inhibition (HI) antibody assay using the same reference strains as above (Beaty et al. 1995). Sera were then tested using a PRNT antibody assay using reference strains of SLE virus (SLE-P15) and EEE virus (D64-837) (Beaty et al. 1995).

**Oral Examination**

The oral cavity of chicks was visually examined for the presence of granulomas as described by Carpenter and Gardiner (1979) and Novilla et al. (1981). Oral lesions matching these descriptions were assumed to be a result of disseminated visceral coccidiosis (DVC) but other causes could not be ruled out by gross examination.

**Fecal Samples**

Fecal samples were collected opportunistically and put in a small jar. In the lab, 2% potassium dichromate was added and samples were stored at room temperature until they were analyzed. Samples were analyzed for the presence of sporulated coccidial oocysts using a fecal flotation method (Sloss et al. 1994).

**Determination of Predation**

Only chicks with radio-transmitters attached were found after death. Predation was determined to be the cause of death if a carcass was recovered and evidence of trauma found at necropsy was consistent with predation. In many cases no carcass was left for recovery, in these instances, predation was judged to be the cause of death if evidence of a predator was observed, such as feathers or feces, at a site where a crane chick was killed.

**RESULTS**

**Predation**

Evidence to indicate predation was available in 8 cases. Bobcat (Felis rufus) predation was identified as the cause of death for 3 chicks based on method of kill, disposition of the carcass, and the presence of bobcat feces at the location the radio-transmitters were recovered. Coyote predation was suspected in the cause of death of 1 chick based on bite marks present on the carcass and the observation of coyotes nearby. Avian predation was suspected as the cause of death for 2 chicks. One chick was found whole with only a single puncture wound in its back and a great horned owl (Bubo virginianus) feather lying next to it. In the second case, flesh had been removed from the bones without damage to the bones, except that the skull was crushed, and there was no evidence from previous captures to indicate disease. Unknown predators were suspected of killing two chicks. In these two cases, feathers and some tissues were found at the sites the radio-transmitters were recovered.

**Disseminated Visceral Coccidiosis**

Sixty-six of 160 (41%) examinations of the oral cavities of 114 live sandhill crane chicks were positive for granulomas. Of 44 fecal samples from 31 individual crane chicks, 7 (16%) (representing 7 individuals, 23%) were positive for oocysts of Eimeria gruis and/or E. reichenowi, one or both of which are etiologic agents of DVC. Three chicks captured multiple times were positive for oral granulomas at one capture but negative at subsequent captures. Two of 5 (40%) carcasses of sandhill crane chicks examined at necropsy were positive for DVC.

There were 27 pairs of siblings that were examined of the 114 sandhill crane chicks examined. Three of these pairs also had fecal samples examined for oocysts of Eimeria spp. No evidence of DVC infection was observed in 12 pairs of chicks, both siblings were positive for oral granulomas or fecal oocysts of Eimeria spp. in 10 pairs of chicks, and in 5 pairs of chicks, 1 individual was positive and 1 individual was negative for oral granulomas or fecal oocysts of Eimeria spp. Based on these data, siblings were considered subsequently to be a single sample for determination of prevalence data. With siblings combined, of 86 chicks examined, 52% were positive for signs of DVC. In all cases of oocyst shedding, either the chick or its sibling had oral granulomas.

Oocysts of either E. gruis or E. reichenowi were found in fecal samples obtained from 7 crane chicks. Three chicks had both E. gruis and E. reichenowi fecal oocysts, 2 had just E.
gruis fecal oocysts, and 2 had just E. reichenowi fecal oocysts. Three of these chicks also had oral lesions, 2 with just E. reichenowi fecal oocysts and 1 with both E. gruis and E. reichenowi fecal oocysts.

Arboviruses

From the 172 serum samples obtained from 115 chicks, 10 were positive for antibodies to SLE virus and 1 was also positive for antibodies to EEE virus. Virus was not isolated from any of the 45 samples collected and analyzed in 2000. All antibody-positive individuals had 90% neutralization titers of 1:10. All positive chicks were estimated to be younger than 9 days of age. For SLE virus, 4 pairs of siblings were both seropositive (positive for antibodies to SLE virus), 1 pair of siblings had a single seropositive chick, and a single chick (with no sibling observed) was seropositive. For EEE virus, 1 pair of siblings sampled in 1998 had a single seropositive chick while both siblings were also seropositive for antibodies to SLE virus. For all subsequent analyses, pairs of siblings were treated as a single sample, if 1 chick was positive or if both chicks were positive this counted as a positive sample, if both chicks were negative they counted as a negative sample. Across all years and in chicks younger then 9 days of age, 25% (6 of 24) samples were positive for SLE antibodies and 4% (1 of 24) were positive for EEE antibodies. Antibodies to SLE virus were detected from crane chicks in both Lake and Osceola Counties. Antibodies to EEE virus were detected only in Osceola County.

Blood Parasites

Blood smears from 114 individual birds were examined during this study. Leucocytozoon gruis (10%), Haemoproteus antigonis (7%), and H. balearicae (3%) were detected in blood smears and reported elsewhere (Dusek et al. 2004). An unidentified protozoan and an unidentified microfilaria were detected in 1 bird each in 1998 and 1999 respectively.

Miscellaneous Conditions

Presence or absence of ant bites was noted during 127 captures, 13 of which had lesions present (10%). Ant bites were assumed when small, approx. 1 mm diameter, raised lesions were observed on the feet and/or legs. As with DVC, other causes could not be ruled out by gross examination. Number of bites counted ranged from 1 to 42 (median = 4, n = 12). Of these 13 chicks, 12 were estimated to be less than 21 days of age. Four of these chicks were subsequently recaptured at 7, 13, 14, and 40 days later at which time no lesions were noted.

A single chigger (Blankaartia sinnamaryi) and associated lesion was detected on 1 of 2 siblings at their initial capture (less than 9 days of age) on the Pruitt Ranch. During the second capture (7 days later), chiggers were detected on the second sibling but not on the first. Fourteen days later, at the third capture, both chicks had chiggers present. Numbers of chiggers were described as ‘numerous’ on the second chick at the second capture, and ‘moderate’ on both chicks at the third capture.

Helminths were found in three chicks. Of 6 carcasses examined, 1 chick (50-60 days of age) had 4 Brachylaima fuscatum in the lower small intestine and 1 Strongyloides sp. in the duodenum. A second chick had a single nematode found in the proventriculus but it was not identified further. An unidentified microfilaria was detected by blood smear examination for a third chick. Seven days after capture this chick was found dead and a complete necropsy was performed but attempts to locate adult nematodes were unsuccessful.

A single chick had an unknown extra-cellular Sarcocystis-like protozoan parasite present on examination of its blood smear. This chick on external examination also had numerous 3 mm x 3 mm (estimated) rounded, raised nodules around the hocks of both legs.

Phagocytized rod-shaped bacteria were detected in the white blood cells of a single crane chick during this study via blood smear examination. This chick disappeared 4 days after capture and it could not be relocated using the radio-transmitter that was attached. The radio-transmitter was recovered 21 days later, but no remains of the chick were observed and it was believed to be dead. Adult sandhill cranes were observed in and around the wetland where this bird was captured, but no chicks were observed with them. A second crane chick had numerous rod-shaped bacteria detected in a swollen area on 1 foot. This chick was also infected with H. balearicae and was anemic and moribund. Diagnosis of the cause of death of this chick was linked primarily to the H. balearicae infection (Dusek et al. 2004).

Capture-related injuries were seen in 4 individuals. Injuries were confined to the legs and did not coincide with radio-transmitter attachment. In all cases chicks were unable to stand well at release. In 1 instance, 2 siblings were both afflicted with this problem. The chicks were captured quickly with no evidence of injury during capture. Both of the chicks were observed the day following capture with parents, but both birds were limping. The problem recurred in 1 of the chicks after handling 2 weeks later with no apparent leg problems. Chick feathers found at the release site the following day indicated that this chick probably did not survive, and it is unlikely that its sibling, not seen at the second capture, survived.

In another instance, a single chick very close to fledging, was chased on foot for approximately 50 m before it fell to the ground and was captured. After normal processing, the chick was unable to stand and died after about an hour. Death was most likely brought on by heat stress and possibly ant harassment following heat stress development. At necropsy, the cause of the leg problem and death was not discovered.

In the final case, a chick (but not its sibling) developed leg problems during capture or handling. On release, it was able to sit on its hocks but could not rise to its feet or walk. After about an hour of trying, the parents started to walk away with its
sibling. At that point the chick was recaptured. The legs were immediately cooled in a nearby wetland as the bird was panting and the bare parts of the legs were very warm. The chick was held overnight and fed mealworms and water. The following day the chick was able to walk although somewhat unsteadily. It was returned to its parents and sibling about 24 hr after capture. Based on observations by individuals that worked on the property this chick and its sibling were believed to have fledged.

One physical deformity was observed. The upper bill of one chick was curved to the left at an approximate 40° angle from the lower bill, which appeared straight and normal. On initial capture, the upper bill measured 55 mm (straight-line measurement, not along the curve of the bill) and a lower bill measurement of 62 mm (as measured from the top of the upper bill where the feathering begins). The distance between tips of the upper bill and lower bill was 42 mm. Tarsus length at this capture was 171 mm. Twenty-two days later, this chick was recaptured. At this time the upper bill was the same length but the lower bill was 80 mm and the distance between the tips of the upper bill and lower bill was 60 mm. Tarsus length at this time was 197 mm. The weight of the chick increased from 915 gm at the first capture to 1185 gm at the second capture.

**DISCUSSION**

**Predation**

Predation has been the most frequent cause of death reported for cranes in studies utilizing radio-telemetry techniques (Nesbitt et al. 1997, Nesbitt and Carpenter 1993). This is especially true for studies involving sandhill crane chicks (DesRoberts 1997, Ivey and Scheuering 1997, Nesbitt and Schweikert 1999). Of the 11 cases for which the cause of death was known or suspected in this study, 8 were linked to predation.

While bobcat predation was determined as the cause of death in 3 cases, it is likely that bobcats killed many of the 20 other crane chicks that disappeared and were suspected dead during this study. Bobcats accounted for the deaths of 31 of 32 released whooping cranes that died between 1993 and 1995 (Nesbitt et al. 1997), as well as for almost half the mortality of subadult greater sandhill cranes experimentally released into central Florida in 1986 and 1987 (Nesbitt and Carpenter 1993). In addition, 1 of 2 whooping crane chick deaths in central Florida in 2000 was attributed to a bobcat (Nesbitt et al. 2001).

Coyotes have colonized Florida recently and appear to be continuing their expansion into the state (Brady and Campell 1983, Wooding and Hardisky 1990). Coyote predation on crane chicks has been well documented in the western U.S. (DesRoberts 1997, Ivey and Scheuering 1997, Littlefield and Lindstedt 1992) and was first documented in Florida in 1993 (Nesbitt and Badger 1995). As coyotes become more common in Florida, it is likely they will account for a greater number of crane chick deaths.

With the exception of 1 study, avian predation on sandhill crane chicks seems to be rarely reported. In Oregon, U.S.A., avian predation accounted for 25 of 64 predation cases documented (Ivey and Scheuering, 1997). Golden eagles (*Aquila chrysaetos*) and great horned owls accounted for 9 and 10 of the cases, respectively. In 3 other studies, avian predation of crane chicks was not observed or was minimal (DesRoberts 1997, Littlefield and Lindstedt 1992, Nesbitt and Schweikert 1999). In all of these studies there were numerous unknown fates of individual birds. At least some of these unknowns could have been due to avian predation. In this study, only 2 birds were suspected of being killed by avian predators.

In all studies of chick survival, predation has played an important role as a mortality factor. Crane chicks, due to their relatively long prefledging period, precocial nature, and tendencies to feed in upland pastures, seem to make themselves suitable and easily available prey items. Numerous additional factors, including infectious and noninfectious diseases, may also play a role in the high predation mortality. One chick in this study had 2 preexisting disease conditions, DVC and infection with *H. balearicae* (Dusek et al. 2004). This chick was found moribund and abandoned by its parents. Likely the death of this chick would have been attributed to predation had it been first found by a predator. In a second chick that was killed by a bobcat, DVC was noted at necropsy and could have predisposed this individual to predation. Predation is an important component of chick mortality, but the role of disease in predation may be difficult to assess. Most studies of crane chicks have not addressed health parameters of marked birds until after a carcass is recovered. This method may not yield the primary causes of mortality and may lead to an over estimate of how important predation is to a population of birds.

**Disseminated Visceral Coccidiosis**

In one chick that was necropsied, DVC was severe enough that it may have predisposed the chick to predation. Sandhill crane chicks are reported to suffer mortality after experimental exposure to high doses of oocysts of *E. gruis* and/or *E. reichenowi* (Novilla et al. 1989). While many of the chicks that survived beyond approximately 3 weeks of age and examined in this study developed oral lesions consistent with DVC, they were likely not exposed to as high a dose of oocysts of *Eimeria* as experimental chicks have been. High dose *Eimeria* exposure in wild chicks is probably very rare under natural conditions or else seriously ill chicks are difficult to find.

**Arboviruses**

Antibodies to both SLE and EEE viruses were detected only in crane chicks estimated to be less than 9 days of age, and were suspected to be from maternal transmission of antibodies and not antibodies acquired through natural exposure. If mosquito borne transmission had occurred, antibodies should have
been detected throughout the age range of captured chicks. Additionally, antibody titers were barely detectable and did not increase with age or persist longer than 9 days after hatch. Maternal transmission of arbovirus antibodies has been reported in other avian species (Kissling et al. 1954, Reeves et al. 1954).

Antibodies believed to have developed from natural infection with EEE and SLE viruses have been detected previously in near-fledged (approximately 60 to 70 days of age) sandhill crane chicks in Osceola and Lake counties from 1992 to 1994 (Forrester and Spalding 2003). Antibodies to EEE and SLE were detected in 19% and 2%, respectively, of chicks sampled and contrast with the lack of antibodies in chicks older than 9 days of age in this study. EEE and SLE virus transmission to sentinel chickens occurs sporadically from year to year and also varies in the month of onset from year to year (Day 1989, Day and Stark 1996). Additionally, yearly variation in rainfall may influence mosquito populations, which could subsequently affect transmission patterns of arboviruses. Drought conditions, as seen throughout most of this study, may severely limit arboviral transmission. This variation may account for the dissimilar results between this study and the 1992-94 study.

**Blood Parasites**

A single infection of a *Sarcocystis*-like protozoan was detected in the peripheral blood of one crane chick. Protozoan organisms that fit this description have not been reported before from sandhill cranes, although species of *Eimeria* can produce a similar looking merozoite that may be found in peripheral blood. Other blood parasites are discussed elsewhere (Dusek et al. 2004).

**Miscellaneous Disease Conditions**

A number of other etiologic agents of disease and disease conditions were observed during this study. These included ant bites, chigger infestation, helminth infection, and bacterial infection, as well as a bill deformity and leg problems associated with capture.

Littlefield (1987) suggested that harassment by the stinging ant *Myrmica incompleta* led to the death of sibling sandhill crane chicks in Oregon as the adults were unable to brood comfortably in unseasonably cool temperatures and as a result the chicks died from exposure. Chiggers and their associated lesions were first reported from four Florida sandhill cranes by Spalding et al. (1997). Helminths are found commonly in adult sandhill cranes in Florida (Forrester and Spalding 2003). Bacterial infection has been reported rarely in sandhill crane chicks. *Staphylococcus aureus* was indicated as a cause of death in California (DesRoberts 1997) and Forrester and Spalding (2003) have identified several species of bacteria from sandhill cranes. Little information is available, however, on the effects of any of these conditions on sandhill crane chicks.

Leg problems are common in crane chicks in captivity (Olsen and Langenberg 1996). Leg problems were reported in crane chicks captured just prior to fledging that were handled in a similar way as chicks in this study, but were much older (M. G. Spalding, unpublished data). In that case it was believed that nutritional deficiencies associated with eating mole crickets might have made those birds susceptible to leg injury. Florida sandhill cranes can average growth in their legs of up to 1 cm per day and this may make leg joints, tendons, and muscles susceptible to injury. Injury to chicks in this study appeared directly related to capture and handling of chicks, although it is not known if other preexisting conditions may have predisposed the chicks to leg injuries. Exertional myopathy has been previously reported in sandhill cranes (Hayes et al. 2003) and may explain the injuries observed. Muscle weakness following the stress of capture may also be the cause of the observed responses in these chicks rather than physical injury.

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**LITERATURE CITED**


INJURIES AND ABNORMALITIES OF SANDHILL CRANES CAPTURED IN FLORIDA

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Abstract: Observations of gross pathological abnormalities were made during handling of sandhill cranes (Grus canadensis) captured for banding in Florida. One hundred fifty-six of 1,331 (11.7%) cranes examined showed evidence of one or more anomalies that were the result of disease, congenital deformity, or injury. Most frequent were abnormalities of the legs and feet, followed by abnormalities of the bill. Injuries of the eyes, head, and neck were also noted. Many of these birds were observed subsequent to banding and survived for several years with their injuries, though some never succeeded in reproducing.

Key words: pathology, cranes, disease, Florida, Grus canadensis, injuries, sandhill cranes.

The Florida Fish and Wildlife Conservation Commission began capturing sandhill cranes (Grus canadensis) for banding in 1968 (Williams and Phillips 1972). After 1974, as part of an expanded study of plumage (Nesbitt and Schwikert 1998), each crane handled was examined incidentally for signs of injury or disease. The number of cranes we handled each year increased after 1980 when we accelerated banding and color marking of sandhill cranes as part of a program to determine the feasibility of establishing a non-migratory population of whooping cranes (G. americana) in Florida (Nesbitt et al 1997). Here we present a summary of type, frequency of occurrence, and possible consequence on life history of gross physical abnormalities that were due to congenital deformities, disease or trauma sustained under free ranging conditions, i.e. not capture related. Capture related injuries and mortalities were rare and addressed in another paper (Nesbitt 1984).

METHODS

Cranes were captured in north central Florida, on or near Paynes Prairie State Preserve (29°36’N, 82°13’W) in Alachua County. Captures were made with the use of alpha-chloralose as described in Nesbitt (1975) and Bishop (1991). Each bird was weighed and measured (see Nesbitt et al. 1992) when captured; during subsequent recaptures only weights were consistently recorded. However, each time a bird was handled it was checked for any signs of gross pathology or abnormalities. Lesions observed within the oral cavity, which were commonly seen, are not included here.

In 1974, a scheme was implemented to uniquely color mark each crane captured (Nesbitt et al. 1992). This facilitated monitoring individual cranes post-capture and allowed us to evaluate how abnormalities effected survival and behavior in subsequent years.

RESULTS

From 1974 through 1999, 1,331 cranes were examined, including 365 recaptured birds. Of these, 156 (11.7%) had detectable injuries or abnormalities. Several of these anomalies dramatically altered the crane’s appearance and, in all likelihood, its ability to function normally.

A 2.6 year old female captured 30 November 1989 had several tumors on both legs. One of these was a large (6 cm diameter) benign tumor on the tibiotarsal joint of the right leg (Fig. 1) and there were a number of smaller tumors on both legs. The combined effect of these lesions was enough to interfere with the bird’s ability to walk. The bird died during surgery to remove the larger tumors. Six other cranes we captured had lesions that appeared similar, though much reduced. These tumors contained viral particles. The virus causing these tumors has not yet been identified, but poxvirus, which occurs in sandhill cranes (Simpson et al. 1975, Forrester and Spalding 2003), was ruled out.

We captured 5 individuals that had suffered fracture to the tibiotarsus or tarso-metatarsus that had apparently healed spontaneously. The majority of these birds appeared normal. However, one bird was left with a severely twisted leg and an unnatural gait. Deformities of the legs were seen in 5 other cranes that were missing part of the lower leg or a foot.

Several of these cranes were seen following release. Those that lost a lower leg were either never seen again or only seen for a few days after release. Some of the birds with healed leg or toe fractures were seen for up to 2 years after release. One individual of unknown sex was seen 23 times over a period of 4 years following initial capture, but was never recorded as paired. Another crane observed 7 times over 3 years following initial capture was seen as a member of a pair, but never with

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young.

We recorded 25 abnormalities of the bill, the second most frequently seen deformation. One individual, with a severely crossed bill (Fig. 2), was captured first as a chick in the company of its parents. It was unable to feed itself after leaving the family and when recaptured, soon after separating from its parents, had lost nearly 50% of its mass and was obviously starving. Efforts to correct the deformity were unsuccessful and the bird was euthanized. Seven other individuals with severely crossed, bowed, or broken bills seemed to be able to survive with the defect and form pair bonds, but none ever succeeded in reproducing. One crane, first captured as a chick, had a deformation of the bill that left it noticeably de-curved (Fig. 3). The bird was seen 24 times between 4 September 1987 and 16 January 1991. It did form pair bonds with several individuals, but they never lasted more than a few days.

Three of the 5 cranes captured that were blind in one eye were seen for several years following initial banding. One seen 50 times between 15 September and 26 October 1991 was paired with 4 different birds, but never produced young. Another individual seen 23 times between 1 August 1984 and 23 September 1986 was paired and nested, but never successfully reproduced. The third single-eyed bird was seen 13 times between 17 December 1984 and 21 December 1988, but never noted as paired. The other 2 cranes blind in one eye were not seen again after the year of capture.

The scarred combs and necks of 11 individuals were perhaps the result of conspecific attacks. We have seen 3 aggressive encounters between individuals that resulted in mortality.

![Fig. 1. Tumors on the right leg of a subadult sandhill crane captured in Florida 30 November 1989.](image1)

![Fig. 2. Crossed-bill of a subadult Florida sandhill crane captured in Florida 17 April 1987.](image2)
Fig. 3. De-curved bill of a subadult Florida sandhill crane captured in Florida 4 May 1988.

Fig. 4. Scarred comb of subadult male Florida sandhill crane captured in Florida 3 August 1983.
In all cases death was from stabbing to the back of the head. A sub-lethal attack like this would leave a scar such as shown in Figure 4. A dead crane that was reported by the observer to have fallen from the sky out of a passing flock, had a wound to the back of the head (consistent with an aggressive attack) indicating it might have been attacked in flight by another crane.

We observed 2 instances of birds kicking forward during handling that resulted in a long neck laceration from a toenail. Such wounds, which could occur during territorial disputes, would leave a similar scar. This may also explain the bird with a portion of its tongue protruding out through the cervical skin (Fig. 5) of an adult female crane. The crane was seen 49 times between initial capture on 24 February 1983 and 5 May 1989. When seen it was always paired with the same individual though they never produced young.

The abnormal tongues of four other cranes could have resulted from disease, injuries, or congenital abnormalities. Although the parasite has not been documented in sandhill cranes, we observed capillarid nematodes and eggs present on the tongue of a whooping crane, resulting in a noticeable deformity (Forrester and Spalding 2003).

A juvenile crane captured 19 March, 1990 exhibited a severely deformed neck (Fig. 6). It was examined and radiographed at the University of Florida School of Veterinary Medicine and was determined to have scoliosis. This individual was seen 6 times between capture on 19 March 1990 and 3 February 1992. Though it survived with the condition, and was able to migrate, it was never seen paired.

We handled several other cranes with individually unique.
peculiarities. One bird had white middle toenails on both feet. Another had double nails on the hallux of each foot (Fig. 7). The tarsi of a third individual were noticeably flattened on the ventral aspect. Reasons for these abnormalities were not obvious; they could have been genetic or due to injuries that occurred early in the bird’s development.

DISCUSSION

Some of the injuries to the legs and feet may be a consequence of collisions with power lines or injuries from fences. Power transmission lines are known to cause mortality in cranes (Walkinshaw 1956, Krapu 1974). Adverse weather conditions can increase mortality associated with power lines (Wheeler 1966). Marking of lines has been an effective way to reduce instances of collision (Brown and Drewien 1995). Agricultural fencing has caused death and leg injury to cranes, but potential impacts can be reduced (Wood and Nesbitt 2001). Based on our observations it is apparent some cranes survive impacts with fences and power lines, although depending on the extent of injury, they may not be capable of functioning normally after recovery.

Losses of the legs and feet for sandhill cranes significantly affected their ability to walk or stand normally and likely interfered with their ability to feed normally or defend themselves against aggression from other cranes and predators. Causes could not be determined with certainty, but the loss of a foot or lower leg could follow a fracture that failed to heal and became necrotic. Such losses of distal extremities also could have followed frostbite to the feet or toes that led to appendage necrosis (Calle et al. 1982). Deformation of the bill, often first seen in chicks, may in some cases have been the result of injuries suffered soon after hatching, while their bills were growing rapidly.

Approximately 12% of the sandhill cranes we handled had noticeable signs of injury or disease. While many of them survived initially, in some cranes the long term effect may have compromised their ability to function normally. While survivable, the loss of a leg or foot, the loss of an eye, or a significant deformation of the bill may reduce a bird’s opportunity to secure a mate, feed their young, or otherwise successfully reproduce.

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LITERATURE CITED


WHOOPING CRANE TITERS TO EASTERN EQUINE ENCEPHALITIS VACCINATIONS

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Abstract: In 1984 an epizootic of eastern equine encephalitis (EEE) virus killed 7 of 39 (18%) whooping cranes in captivity at the Patuxent Wildlife Research Center in Laurel, Maryland, USA. Since that time whooping cranes have been vaccinated with a human EEE vaccine. This vaccine was unavailable for several years, necessitating use of an equine vaccine in the cranes. This study compared the antibody titers measured for three years using the human vaccine with those measured for two years using the equine form. Whooping cranes developed similarly elevated titers in one year using the human vaccine and both years using the equine vaccine. However, in two years where the human vaccine was used, the whooping cranes developed significantly lower titers compared to other years.

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Key words: Grus americana, eastern equine encephalitis, titers, vaccine, virus, whooping crane

Eastern Equine Encephalitis (EEE) is a clinically important disease of horses, people, and some birds including whooping cranes (Grus americana). EEE is classified as a zoonotic vector-borne alpha virus. The virus is found in eastern North America and is maintained and amplified by a mosquito-wild bird cycle. Native wild passerines carry the virus and initiate the cycle, with viremic birds being found 37-51 days before virus is first detected in mosquitoes beginning in July or August and lasting through October (Cranes et al. 1994). The virus is then spread by the mosquitoes and amplified in the hatch-year passerines. EEE does not typically produce morbidity or mortality in native passerines, but has been known to cause mortality in non-native birds (pheasants, emus; Tengelsen 2001), horses, bats (Main 1979), and humans.

Vaccination as a tool to control arbovirus infections in horses is a widespread practice that provides effective protection (American Association of Equine Practitioners, 1995; Tengelsen et al. 2001). Commercially available equine vaccines for EEE are used to protect emus from the disease (Tengelsen et al. 2001). Between September 17 and December 15, 1984 an epizootic of EEE killed 7 of 39 captive whooping cranes at the Patuxent Wildlife Research Center, Laurel, Maryland USA (Dein et al. 1986, Carpenter et al. 1989). Following the 1984 EEE epizootic at Patuxent, all whooping cranes began receiving annual injections of EEE vaccine (Clark et al. 1987; Olsen et al. 1997). There were no challenge studies done with the endangered whooping cranes. Naturally occurring epizootics were documented in sentinel birds and in mosquitoes, with no morbidity or mortality in captive whooping cranes. This led to the conclusion that the vaccination program was efficacious (Olsen et al. 1997). In 2000 and 2001, the human EEE vaccine previously used was not available for the whooping cranes at Patuxent. As an alternative; the birds were vaccinated with a commercially available equine vaccine.

The objective of this study was to compare antibody titer levels observed in years when the human vaccine was used with the 2 years when the equine vaccine was used. When an equine vaccine was first tested in the 1980’s, the titer levels were lower than those seen with the human vaccine (Clark et al. 1987), and we wanted to discover if this was still true with the currently available equine vaccine.

METHODS

All adult whooping cranes housed at Patuxent were kept in 15 x 20 m outdoor pens. Very young whooping crane chicks being costume-reared for release programs spent the first 7-10 days confined indoors in 3 x 3 m pens, but afterwards were in indoor/outdoor pens until 40-50 days of age, after which time they were housed totally outside.

All whooping crane chicks received their first injection of EEE vaccine in July. For 1989-1999 this was 0.5 ml intramuscular injection of the PE 6 WRAIR strain human EEE vaccine (The Salk Institute, Government Service Division, Swiftwater, Pennsylvania, USA). This was followed 1 month later by an intramuscular injection of 1.0 ml. Yearly revaccination using the same 1.0 ml dose of the PE 6 WRAIR EEE vaccine occurred in late August or early September, to coincide with the seasonal peak of activity (August-October) for the EEE carrying mosquito (Culiseta melanura) at Patuxent (Pagac et al, 1992).

In 2000 and 2001, all adult whooping cranes received a 1.0 ml intramuscular dose of Encephaloid M (EEE and western equine encephalitis vaccine, Fort Dodge Laboratories, Fort Dodge, Iowa USA) in August of each year. All whooping crane chicks received the same Encephaloid M as 0.5 ml intramuscularly in July and 1.0 ml intramuscularly in August of their hatch year.

Blood samples to obtain serum for titers were collected...
in late October or early November of each year during rou-
tine health examinations of the whooping cranes. Serum was
shipped frozen to the USGS National Wildlife Health Center,
Madison, Wisconsin, USA for analysis by hemaglutination-inhibition testing (HI, 1994-1997) or by serum neutralization
testing (SN, 2000-2001) at the National Veterinary Services
Laboratory, Ames, Iowa, USA. We analyzed the EEE titers for
1994, 1996 and 1997, years in which the human vaccine was
used, and the most recent years (2000, 2001) when the equine
vaccine was used. Due to budget constraints, no titers had been

Data were analyzed with a repeated measure analysis of
variance (ANOVA) using a compound symmetry model in the
mixed-models procedure of SAS (Statistical Analysis System,
Version 6.12; 1997). The subject factor was crane identification
number nested with gender. Prior to analysis, titers were trans-
formed with a log 10 transformation to help achieve normality
and homoscedasticity of residuals. Pairwise comparisons were
performed on the least square means using a Tukey multiple
comparison procedure (P < 0.05).

RESULTS AND DISCUSSION

Antibody titers were available from a total of 52 whooping
 cranes for the years 1994-1997 (human vaccine) and 2000-2001
(equine vaccine). For the 3 years when the human vaccine was
used, the titers were highly variable (Table 1). The titers for
1994 were very low, while the 1996 titers were high, equiv-
alent to those found with the equine vaccine. The 1997 titers
were higher than 1994 but lower than 1996. Table 1 shows the
untransformed means, sample sizes, and standard deviations,
as well as pairwise comparison results of the log-transformed
least square means. The mean titers for 1996, 2000, and 2001
were not significantly different (P > 0.05) from each other. The
titer means for 1994 and 1997 were significantly different from
each other and were different from 1996, 2000, 2001 EEE mean
titers (P < 0.05). We used two different tests to determine the
titers (HI and SN) but saw no differences in titer levels in 1996
(HI), 2000 or 2001 (SN). Titers seen with the human vaccine
were considered protective due to the absence of morbidity or
mortality seen in whooping cranes in years since 1984 when
EEE was detected in mosquitoes and sentinel birds (Olsen et
al. 1997). The equine vaccine tested produced titers equal to or
higher than those produced by the human vaccine, which would
suggest adequate protection.

Initial testing of a commercially available equine EEE vac-
cine and the Salk human EEE vaccine in the 1980's had shown
superior titer levels when using the human vaccine (Clark et.
al, 1987). Therefore, the decision was made to vaccinate the
captive whooping cranes with the human vaccine. Unavailabil-
ity of this vaccine starting in 2000 prompted the switch to an
equine form of EEE vaccine. These results show that the titers
obtained from this new equine EEE vaccine equal or exceed the
titers seen with the human EEE vaccine used in the past. The
human vaccine continues to be unavailable today, and, given
current world events, it is unlikely to be released by the military
any time soon. Therefore, continued use of an equine EEE vac-
cine appears to be an appropriate management tool to prevent
this disease in captive whooping cranes.

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<table>
<thead>
<tr>
<th>Year</th>
<th>Sample Size (n)</th>
<th>Geometric Mean</th>
<th>Standard Error</th>
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<tr>
<td>1994</td>
<td>33</td>
<td>6.08</td>
<td>1.22</td>
<td>A</td>
</tr>
<tr>
<td>1996</td>
<td>39</td>
<td>88.13</td>
<td>1.21</td>
<td>B</td>
</tr>
<tr>
<td>1997</td>
<td>37</td>
<td>15.07</td>
<td>1.21</td>
<td>C</td>
</tr>
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<td>51</td>
<td>82.64</td>
<td>1.19</td>
<td>B</td>
</tr>
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</table>

\(^a\) Means with the same letter are not significantly different (P > 0.05), based on Tukey’s multiple comparison procedure of the least square means generated from the log-transformed titer levels in the repeated measures ANOVA.
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LITERATURE CITED


ANNUAL MOVEMENTS OF PACIFIC COAST SANDHILL CRANES

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Abstract: The subspecies composition of migratory sandhill cranes (\textit{Grus canadensis}) which stage and winter along the Lower Columbia River in northwest Oregon and southwest Washington is uncertain, but may include all 3 using the Pacific Flyway: lesser (\textit{G. c. canadensis}), Canadian (\textit{G. c. rowani}), and greater (\textit{G. c. tabida}). However, the status of \textit{rowani} has been debated. During 2001-02, we captured and marked 8 cranes using a noose line trapping technique, and attached Platform Transmitter Terminals (PTTs) to 6 to ascertain locations of their breeding areas, migration corridors and winter sites. Morphometric data were collected for subspecies determination. From measurements and their summer distribution, we conclude that they are likely the intermediate \textit{rowani} form. Because of their limited numbers, distinct coastal migration path, and habitat issues at breeding, staging, and wintering areas, we recommend that conservation efforts be increased and that they be managed as a unique population.

\textbf{PROCEEDINGS NORTH AMERICAN CRANE WORKSHOP 9:25-35}

\textbf{Key words:} Alaska, British Columbia, California, Canadian sandhill crane, \textit{Grus canadensis rowani}, noose line, Oregon, Pacific Flyway, Ridgefield National Wildlife Refuge, satellite tracking, Sauvie Island Wildlife Area, Washington.

Most sandhill cranes (\textit{Grus canadensis}) migrating in the Pacific Flyway between breeding grounds in Alaska and British Columbia (B.C.), Canada, and wintering areas in California use an interior route, east of the Cascade Mountains through B.C., Washington, Oregon, and northeast California (Littlefield and Ivey 2002, Petrula and Rothe 2005). A smaller group of cranes migrate, stage and winter along the Lower Columbia River, west of the Cascades in Oregon and Washington. They primarily use Ridgefield National Wildlife Refuge (NWR), Washington, Sauvie Island Wildlife Area (WA), Oregon, and surrounding areas (Littlefield and Ivey 2002). However, the subspecies composition, nesting areas, migration routes and chronology, and other wintering sites of these flocks were unknown. In 2001, we initiated a study of sandhill cranes wintering in the Lower Columbia River region and used satellite telemetry techniques to determine their seasonal and annual movements and identify subspecies wintering in the region.

\textbf{STUDY AREA}

Cranes were captured at 2 sites in the Lower Columbia River region: Ridgefield NWR and Sauvie Island WA. Ridgefield NWR lies between channels of the Columbia River and contains 2,085 ha in Clark County, Washington. Across the river in Oregon, sets the 4,673 ha Sauvie Island WA, in Multnomah and Columbia counties. Cranes regularly moved between these 2 sites, and also used private agricultural fields, including Squaw Island, Vancouver Bottoms, and Woodland Bottoms in Washington, and east of Scappoose along the Multnomah Channel in Oregon. Habitats used included foraging areas (primarily corn and barley fields, pastures, and wetlands) and roost sites. The most consistent roost locations were shallow wetlands on and near Ridgefield NWR, including the mostly private Canvasback Lake and Wigeon Pond on Bachelor Island, and Campbell Lake on the Roth Unit; smaller wetlands were occasionally used, particularly on the Roth Unit. At Sauvie Island, Sturgeon Lake was the principal roost site.

\textbf{METHODS}

Trapping efforts were conducted intermittently between 21 October 2001 and 4 April 2002 in order to increase our chances of capturing unrelated birds. We captured cranes using noose lines, an ancient bird-catching technique from India recently introduced to North America (Hereford et al. 2000). We constructed our own lines from a template provided by T. Grazia of Mississippi Sandhill Crane NWR, with some modifications. To construct the nooses, we used 100-lb test monofilament fishing line to form loops of about 15 cm in diameter, and attached each to a wooden stake (12 cm long, 0.64 cm diameter) made from pine dowels. Stake ends were sharpened to a point and stakes with nooses were then tied to a nylon cord about 30 cm apart, with 25-50 on each line. Snap swivels were tied at each end of the lines so they could be linked together.

We located crane foraging sites and returned after dark to bait potential trapping locations with partially shucked ears of field corn. After cranes used a bait site, lines were set during pre-dawn hours by pushing stakes into the earth about 20 cm apart to form a wall of upright, overlapping nooses. Several lines were placed at each site, and weights were attached to the ends to prevent entangled birds from flying away with them. The noose lines were monitored by a distant blind with binoculars and spotting scopes to minimize disturbance. Cranes feeding on the bait had to do so in close proximity to nooses, and if they stepped into one, their leg or foot became snared.

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Leg strain was minimized by the elastic nylon line and the few stakes which were pulled from the soil by struggling birds.

Captured cranes were hooded to limit stress and the following measurements were taken to delineate subspecies: exposed culmen (base of the upper mandible to the tip), body mass (to the nearest gr), nares to tip of culmen (anterior end of nostril to tip), tarsus (tibio-tarsus joint to the distal edge of the last leg scale above the toes), and wing chord (unflattened wing from carpal joint to tip of longest primary). We then attempted to determine subspecies by comparing our data to those in the published literature. A blood sample was also collected to determine sex and for genetic analyses. Individual cranes were assigned a number between 1 and 8 in the order they were captured for purposes of identification in the text.

If multiple birds were captured in the same flock, only 1 was fitted with a PTT (30g Birdborne) manufactured by North Star Science and Technology, LLC (Technology Center Bldg. Room 4.036, 1450 S. Rolling Rd., Baltimore, MD 21227 USA) which were mounted on blue plastic leg bands engraved with alphanumeric codes. These satellite transmitters were placed above the tibio-tarsus joint, with the 2 halves attached by rivets and quick-drying epoxy (Ellis et al. 2001). The opposite leg was marked with 2 short colored plastic bands of a unique combination and a U.S. Fish and Wildlife Service (USFWS) aluminum band. Other cranes captured in the same flock received colored plastic and USFWS bands only. PTTs were programmed to activate for 8 hrs after 60 hrs of deactivation in order to last about 1 year; locations were recorded from satellites about every 3 days. Cranes were tracked via the Argos Satellite System with data downloaded via the Internet and points were mapped electronically.

RESULTS

We captured 4 cranes at Ridgefield NWR (2 in November 2001, and 2 in February 2002), and 4 at Sauvie Island WA (3 in March and 1 in April 2002). Measurements of these birds are summarized in Table 1. Results of genetic analyses of mitochondrial DNA assigned all 8 birds to the G. c. tabida subspecies (K. Jones, Kansas State University, personal communication); however, this grouping includes birds which would be classified as G. c. rowani, morphologically.

Longevity of the PTTs varied; 2 PTTs lasted 4 months, one 9 months, and the other 3 lasted 13-16 months. Cranes 1 and 2, captured in November 2001, wintered in the Lower Columbia River region and all 8 cranes remained in this region until spring migration. The 2 cranes without PTTs were last observed in late March 2002, while the first PTT birds moved north by 13 April, with the last migrating by 19 April. Data from crane 3 suggested that the migration route may have followed the Columbia River northwest, and all birds proceeded north along a coastal route. Their path followed the Washington coast, crossed Cape Flattery on the northwest tip of Washington, continued across central Vancouver Island, and then along the coast of B.C. (Fig. 1). All cranes arrived within their summer ranges by 21 April 2002.

Final summer destinations were primarily the B.C. coast: Dowager Island (Crane 5), Princess Royal Island (Crane 8), McCauley Island (Crane 2), and near Port Edward, B.C., the only mainland site (Crane 7). Two other cranes traveled north to Dall Island (Crane 3) and Prince of Wales Island (Crane 1), Alaska. Cranes 1 and 7 spent several days at staging areas within their summer range before moving to a final destination, including one that reached southern Alaska but backtracked south to B.C. All 6 birds summered at these locations where we presume they nested (Fig. 2).

Only 3 PTTs were transmitting at the onset of fall migration. Crane 7 began to move south by 6 September 2002, and Crane 1 by 14 September; average time spent on the breeding grounds was approximately 132 days. A third PTT (Crane 8) continued to send data from the same B.C. location through the winter and into the following summer, and we presume this bird either died or the PTT became detached; however, it may have overwintered, as there are a few winter records for the nearby Queen Charlotte Islands (Campbell et al. 1990). At the onset of fall migration Crane 7 used several areas just south of Prince Rupert, B.C from 6-19 September before returning to Sauvie Island WA, its original capture site, on 22 September. Crane 1 apparently did not linger in B.C., but used the same migration route as in spring, with data locations to the east of Prince Rupert, and over central and southern Vancouver Island, B.C. It arrived along the East Fork of the Lewis River, just east of Ridgefield NWR, by 24 September. By 27 September, it returned to the Ridgefield NWR/Woodland Bottoms area where it had been captured and spent the previous winter (Fig. 3). It remained in the area until the PTT failed on 4 November 2002. Time spent on migration from summering areas to the Lower Columbia River region was approximately 15 days for these 2 cranes.

By 14 October, Crane 7 shifted to Ridgefield NWR, and by 30 October, it started to migrate south, likely through the Willamette Valley of Oregon, moving through south-central Oregon, just southwest of Klamath Falls, near Lower Klamath NWR, and stopping at Butte Valley Wildlife Area, Siskiyou County, California. By 2 November 2002, it was southwest of Chico in the Sacramento Valley of California (Fig. 3), and remained in that general area for the duration of the winter (approximately 111 days). Total time for migration from summer to final winter locations was 57 days (including 48 days at the Lower Columbia River region) for Crane 7, compared to only 13 days for Crane 1 which wintered in the Lower Columbia River region.

Crane 7 returned to Sauvie Island WA on 24 February 2003, and departed by 16 April, the same date as the previous spring. It arrived back at its previous summer location near Port Edward, B.C. by 19 April. Spring migration time for Crane 1 from California to B.C. also took approximately 57 days with 38 days spent in the Lower Columbia River region.
Table 1. Measurements of sandhill cranes captured at Ridgefield NWR, Washington, and Sauvie Island WA, Oregon, 2001-02.

<table>
<thead>
<tr>
<th>Crane</th>
<th>Exposed culmen (mm)</th>
<th>Nares to tip (mm)</th>
<th>Tarsus (mm)</th>
<th>Mass (g)</th>
<th>Wing chord (mm)</th>
</tr>
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<tr>
<td></td>
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<tr>
<td><strong>Males:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crane 1</td>
<td>118.0</td>
<td>71.0</td>
<td>N/A</td>
<td>4960.0</td>
<td>515.0</td>
</tr>
<tr>
<td>Crane 2</td>
<td>119.0</td>
<td>74.0</td>
<td>200.0</td>
<td>5610.0</td>
<td>545.0</td>
</tr>
<tr>
<td>Crane 5</td>
<td>109.7</td>
<td>72.7</td>
<td>215.0</td>
<td>N/A</td>
<td>492.0</td>
</tr>
<tr>
<td>Crane 8</td>
<td>105.9</td>
<td>71.6</td>
<td>203.0</td>
<td>5500.0</td>
<td>495.0</td>
</tr>
<tr>
<td>Mean</td>
<td>113.2</td>
<td>72.3</td>
<td>206.0</td>
<td>5356.7</td>
<td>511.8</td>
</tr>
<tr>
<td>SE</td>
<td>3.2</td>
<td>0.7</td>
<td>4.6</td>
<td>200.9</td>
<td>12.2</td>
</tr>
<tr>
<td><strong>Females:</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Crane 3</td>
<td>122.5</td>
<td>72.6</td>
<td>208.0</td>
<td>4280.0</td>
<td>460.0</td>
</tr>
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<td>Crane 4</td>
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<td>61.7</td>
<td>194.0</td>
<td>4960.0</td>
<td>495.0</td>
</tr>
<tr>
<td>Crane 6</td>
<td>113.2</td>
<td>72.0</td>
<td>207.0</td>
<td>4450.0</td>
<td>465.0</td>
</tr>
<tr>
<td>Crane 7</td>
<td>103.3</td>
<td>67.8</td>
<td>172.0</td>
<td>4100.0</td>
<td>435.0</td>
</tr>
<tr>
<td>Mean</td>
<td>112.8</td>
<td>68.5</td>
<td>195.3</td>
<td>4447.5</td>
<td>463.8</td>
</tr>
<tr>
<td>SE</td>
<td>3.9</td>
<td>2.5</td>
<td>8.4</td>
<td>185.2</td>
<td>12.3</td>
</tr>
</tbody>
</table>

Fig. 1. Spring migration route of PTT-marked sandhill cranes, 2002.
DISCUSSION

Subspecies

It should be noted that past morphometric studies (Tacha et al. 1985) and more recent studies of crane genetics (Rhymer et al. 2000, Glenn et al. 2002, Petersen et al. 2003) support subspecies designations of tabida and canadensis, but not rowani, and one study suggests that rowani is a hybrid of tabida and canadensis (Peterson et al. 2003). However, the cranes sampled for these studies did not include any from B.C. or the Pacific Flyway. In contrast, studies of chick development (Baldwin 1977) and measurements of specimens and live birds, including those from coastal Alaska, indicated that rowani were probably distinct (Johnson and Stewart 1973, Johnson et al. 2005). Regardless of the genetic uniqueness of what have been called subspecies, the populations of birds differ in a variety of ways, including morphology (Aldrich 1979, Johnson et al. 2005), migrational timing and pathways (e.g., Johnson and Stewart 1973, Petruka and Rothe 2005, this study), and chick development rates and onset of homeothermy (Baldwin 1976). Also, the distributions of the 3 subspecies indicate they generally breed in different areas: most canadensis breed in the arctic and subarctic regions of North America; rowani in boreal and parkland ecoregions of Canada and Alaska; and tabida in various regions of the United States and southernmost Canada (Johnson et al. 2005). Because these different populations behave differently in their annual movements and face different threats, it appears prudent to manage them individually.

Morphological data suggest that the cranes in our study are rowani, while the genetic analysis assigned them to the tabida subspecies; however, this category combines tabida with rowani and 3 other recognized subspecies (G. c. pratensis, G. c. pulla, and G. c. nesiotes) which are very similar genetically. Because of our small sample size, we could not make statistical comparisons of our morphological data nor determine subspecies with absolute confidence. Generally, all measurements fell within the ranges reported for rowani (Walkinshaw 1965, Stephen 1967, Johnson and Stewart 1973, Schmitt and Hale 1997, Johnson et al. 2005) (Figs. 4-8). Our measurements of exposed culmen, mass, and wing chord of males were within the ranges reported for rowani and tabida, while measurements for the nares to the tip of the culmen, tarsus and wing chord of females were within the ranges reported for rowani and canadensis; they were generally smaller than measurements reported for Rocky Mountain Population tabida (Lockman et al. 1987). Johnson and Stewart (1973) noted that wing chord, tarsus, and exposed culmen were the most useful parameters in determining racial composition. Disparities in some measurements may indicate morphological differences between Pacific Flyway and the Central Flyway cranes; most of the morphological and historic data were collected from birds in the Central Flyway.

Fig. 2. Final summer destinations of PTT-marked sandhill cranes, 2002.
In addition, all birds in the hand and those carefully observed in the field appeared to have the physical characteristics of *rowani*. Head profiles were large and flat, similar to those of *tabida* that we had previously handled in Oregon, but with smaller bills. They also lacked the round head and fine, short bill of *canadensis* we had observed in California and eastern Oregon and Washington. We also noted that captured cranes had shorter unfeathered portions of the legs above the tibio-tarsal joint than *tabida*, as multiple colored leg bands had fit well below the feathers on *tabida*, while they overlapped onto the feathers of birds in this study.

There is apparent confusion in historic subspecies designations within the range of these cranes because of the presence of this intermediate-sized subspecies was not described until the mid-1960s (Walkinshaw 1965). Since measurements used for differentiation between *canadensis* and *tabida* overlapped with what is currently identified as *rowani*, historic accounts of cranes in this region were identified as either greaters or lessers. *G. c. canadensis* were reported nesting in southeast Alaska (Gabrielson and Lincoln 1959), while in the Lower Columbia River region, *canadensis* were reported in migration (Anthony in Gabrielson and Jewett 1940:228), but Gabrielson and Jewett questioned this designation without specimens. However, an injured bird that died near Portland, Oregon, was identified as *canadensis* by Jewett (1954). *G. c. canadensis* was reported nesting at Fort Steilacoom, near Olympia, Washington (Suckley and Cooper 1859), but others subsequently questioned this designated and theorized that they were *tabida* (Dawson and Bowles 1909, Jewett et al. 1953). Accounts of migrant subspecies in Oregon’s Willamette Valley have also varied: one author reported that both *canadensis* and *tabida* were present in migration, with a small flock of *canadensis* wintering near Corvallis (Storm 1941), while others described *tabida* in migration but did not mention wintering birds (Woodcock 1902, Gabrielson 1959).
More recent information supports the conclusion that the cranes using the Lower Columbia River region are likely *rowani*. In B.C., coastal-nesting cranes have been reported as *rowani* (Pogson and Lindstedt 1991, Cooper 1996), and this region is within the subspecies’ range described by Meine and Archibald (1996). *Rowani* may also extend north to the central coast of Alaska where some captured cranes at the Copper River Delta had measurements which suggested this subspecies (Herter 1982). In contrast, *tabida* likely nest in the interior of B.C. (Cooper 1996), and *canadensis* which have been PTT-tagged on their breeding grounds at Cook Inlet and Bristol Bay in Alaska migrated through interior B.C., eastern Oregon and Washington, northwest Nevada, and northeast California dur-

![Graph comparing measurements of exposed culmen of sandhill cranes](image1)

**Fig. 4.** Comparisons of measurements of exposed culmen of sandhill cranes (n = 8) to Johnson and Stewart (1973) and Johnson et al. (This Volume) (n = 388).

![Graph comparing mass of sandhill cranes](image2)

**Fig. 5.** Comparisons of mass of sandhill cranes (n = 7) to studies summarized in Schmitt and Hale (1977) (n = 1,811).
ing both spring and fall (Petrula and Rothe 2005), and did not use the Lower Columbia River region.

It is likely that the birds in this study are also associated with the small, remnant group of cranes which breed in the Fraser Lowlands of B.C. near Vancouver. Information on the subspecies breeding there has also been conflicting, as museum specimens have been classified as both *tabida* and *rowani*, and was further complicated by the release of 17 *tabida* young (from the Rocky Mountain Population) in 1981 (project success unknown) (Campbell et al. 1990). However, live birds observed there in 2003 at the George C. Reifel Migratory Bird Sanctuary appeared to be *rowani* (R. Drewien, and G. Ivey, personal observation).

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**Fig. 6.** Comparisons of measurements of nares to tip of bill of sandhill cranes (n = 8) to Schmitt and Hale (1977) (n = 1,475).

**Fig. 7.** Comparisons of tarsus measurements of sandhill cranes (n = 7) to studies summarized in Schmitt and Hale (1977) and Johnson et al. (This Volume) (n = 2,803).
Importance of Study Area for Sandhill Cranes

The Lower Columbia River region is the only major sandhill crane stopover site between northern breeding areas and wintering sites in California. Cranes have been recorded using the region since at least the early 1800s when noted by Lewis and Clark (Burroughs 1961), and 893 “intermediate-sized” cranes were counted on Sauvie Island in 1982 (Pogson and Lindstedt 1991). In recent years, up to 4,273 have been counted in this region during early fall (Littlefield and Ivey 2002). During spring migration, we estimated 1,900 in March 2002; however, we did not have access to all areas. If conclusions of G. c. rowani using the region are correct, then staging counts may represent the entire population nesting in coastal B.C. and southeast Alaska. Historic accounts of cranes using the coast and islands of B.C. have dated back to the late 1700s (Leach 1979).

We obtained limited information on other staging areas, but all appeared to be of minor value to cranes than the Lower Columbia River region, where Crane 7 stayed 38 days in the fall of 2002, and upon returning in the spring of 2003, remained for about 48 days. To the north, Crane 1 remained at Banks Island for almost 2 weeks, and Crane 8 was at Swindle Island for over 1 week; both these areas were just south of summer destinations. Small flocks of cranes have also been reported staging at Burns Bog in the Fraser Lowlands of B.C. in spring and fall (Cooper 1996).

To the south of the Lower Columbia River region, cranes were historically abundant in migration in the Willamette Valley of Oregon in the mid-to late 1800s, and they may have wintered there as well before wetlands were replaced with agriculture and hunting pressure increased (Taft and Haig 2003). Currently, cranes are regularly heard over the valley in migration (Stern et al. 2003). In northeast California, Crane 7 stopped briefly at Meiss Lake, where around 1,500 cranes (tabida and canaden sis) were historically reported to use the area for 3 to 4 weeks (McLeod 1954). Approximately 500 birds spend about 3 weeks there, including color-marked tabida from east of the Cascades (D. Van Baren, Butte Valley WA, Calif. Dept. of Fish and Game, personal communication). Therefore, this area is used by both coastal and interior migrating cranes. Staging crane numbers have increased at Lower Klamath NWR in northeast California in recent years (D. Mauser, Klamath Basin NWRs, personal communication), and Crane 7 may have stopped there as well.

In addition, the Lower Columbia River region also serves as a wintering site for a few hundred cranes. Reports of wintering birds date back as far as the early 1800s by the explorers, Lewis and Clark, but these reports were judged inaccurate by Gabrielson and Jewett (1940). Currently, exact wintering numbers are unknown, but have been as high as 1,000 (Littlefield and Ivey 2002). During our study, the 2 cranes captured in November 2001 (Crane 1 and 2) remained in the region at least 134 and 140 days after capture, respectively, before migrating north, and likely were present at least 30 days prior to capture. The number of rowani wintering in California in 1983-84 was estimated as 258 (Pogson and Lindstedt 1991).

Rowani may also nest in the Lower Columbia River region in very small numbers. The first summer record on Sauvie Island was possibly in 1989 (Johnson 1990), and a pair with young was reported in 2002 (M. Nebeker, Sauvie Island WA,
personal communication). Cranes have also been observed at Ridgefield NWR during the summer (Littlefield and Ivey 2002). Historically, the nesting area of these birds may have extended from Alaska to Oregon.

**Trapping Methods**

While trapping cranes with the portable noose line technique is safe, it has limitations. Cranes apparently could see the nooses, as when only a few were in the area, they carefully stepped around them to feed on the bait, and were only captured when they were crowded on the bait and distracted by each other. Waterfowl appeared much less wary, and were more readily trapped; we caught 9 Canada geese (*Branta canadensis*) and 4 mallards (*Anas platyrhynchos*). Unfortunately, their capture hindered chances of catching cranes, which were alert when waterfowl were captured and flushed when we removed waterfowl from lines. We found no evidence of injuries to any birds captured by this technique.

Regardless of the method, other factors would hinder any trapping efforts in the study area. The cranes here were exception-ally wary, so that we often had to watch the bait site with a scope from > 0.8 km away or they would not approach; they were much more sensitive to our presence than *tabida* we had captured at Malheur NWR in southeast Oregon. This behavior is likely due to their remote nesting grounds and limited contact with humans. Also unlike *tabida*, they completely ignored piles of whole-kernal corn which we used for bait, a popular entice-ment at Malheur NWR; they preferred field corn cobs partially husked to expose the kernels. At Sauvie Island WA, after much of the available corn was consumed, cranes showed minimal interest in our bait. They fed mostly by digging, and were likely searching for nut sedge (*Cyperus esculentus*) (M. Nebeker, Manager, Sauvie Island WA, personal communication).

Trapping difficulties were compounded by the daily unpredictability of these birds in their feeding and roosting habitats. This behavior may have been linked to regular disruptions of feeding birds by bald eagles (*Haliaeetus leucocephalus*), coy-otes (*Canis latrans*), and low-flying craft. Use of wetland sites was also irregular; heavy rains and high tides caused rising wa-ter levels and consequent shifting of roost areas. Trapping was further complicated with the opening of goose hunting when cranes were flushed from their roosts before dawn, apparently causing about 700 of the 1,000 birds present to migrate from the area on opening day.

**CONCLUSION**

Sandhill cranes captured and observed at the Lower Colum-bia River region appeared to be *rowani* based on morphological measurements, general features in the hand and in the field, migration patterns, and summer locations. While all 3 subspecies have been reported to be possible in the area in recent years (Littlefield and Ivey 2002, Stern et al. 2003), we found no evi-dence of the presence of *canadensis* or *tabida*. Perhaps they use the region during early fall migration, but none were identi-fied during late fall or spring. Although recent genetic evidence concludes that *rowani* and *tabida* should be considered the same subspecies, given that there are morphological and their breed-ing distribution does not appear to overlap in the Pacific Flyway they should be considered separate populations.

Currently, all crane subspecies are considered Endangered in Washington (Littlefield and Ivey 2002) and Vulnerable (Blue-listed) in B.C. (Blood and Backhouse 1999). The Lower Co-lumbia River region is critical for these cranes, as it is their only major staging area between northern breeding and California wintering areas, and also serves as a wintering site for several hundred. Considering that this area is near the metropolitan complex of Portland, Oregon, and Vancouver, Washington, the threat of loss of privately-owned crane habitats is significant. Some vital areas have recently been lost to agricultural con-versions to incompatible crops such as tree nurseries, flowers, berries, and industrial, residential, and public recreation develop-ments, and the possible expansion of the Port of Vancouver poses an additional threat of habitat loss (Littlefield and Ivey 2002). In addition, disturbances at roost sites occur on both public and private lands (e.g., waterfowl hunting).

Potential threats exist at other areas which at least some of these birds utilize. On the central coast of B.C., logging, live-stock grazing, and hydrocarbon exploration and development potentially threaten breeding crane habitat (Cooper 1996). In the lower Fraser River valley (Fraser Lowlands) in B.C., peat harvest and a landfill which will continue to grow and possi-bly affect water quality are habitat issues at Burns Bog, and disturbance may be responsible for declines in breeding pairs there and at nearby Pit Polder (Cooper 1996). Loss of habitat and disturbance were likely factors in the extirpation of nesting cranes from Vancouver Island since 1941, as well as Lulu Island in the lower Fraser River Valley since 1946 (Cooper 1996). In Alaska, cranes are susceptible to sport and subsistence hunting. For Central Valley of California, crane wintering habitat has been replaced by urban expansion and conversion to incompat-ible crops (e.g., orchards and vineyards) (Littlefield and Ivey 1999). Therefore, the small size of this population of coastal-nesting cranes, coupled with threats to their habitats at breed-ing, staging, and wintering areas, merits elevating conservation efforts and managing them as a population, separate from the interior-nesting *tabida*.

**ACKNOWLEDGMENTS**

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cilitated our use of Ridgefield NWR for trapping and housing, and Mark Nebecker of Sauvie Island WA supported our efforts there. Tracy Grazia of the Mississippi Sandhill Crane NWR kindly demonstrated use of the noose line system and assisted with early field work. Joe Engler and Eric Anderson of Ridgefield NWR helped with logistics and early capture attempts, and Mark Stern of The Nature Conservancy discussed local crane issues and donated one morning to assist with fieldwork. Ken Jones of Kansas State University, Manhattan, conducted mitochondrial DNA analysis and determined the sex of the birds we captured. Comments on earlier drafts provided by John Connelly, Rod Drewien, and Bruce Dugger were greatly appreciated.

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A FRESH LOOK AT THE TAXONOMY OF MIDCONTINENTAL SANDHILL CRANES

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Abstract: The midcontinental population of sandhill crane (Grus canadensis) includes about 500,000 birds and provides valuable recreational crane-watching and hunting opportunities in Canada and the United States. It comprises three subspecies, one of which (G. c. rowani) was of uncertain taxonomic status and another of which (G. c. tabida) merited protection from excessive harvest due to its small population size. We obtained measurements of cranes used by Johnson and Stewart (1973) and additional crane specimens to 1) evaluate the subspecies designation of midcontinental sandhill cranes and 2) to seek improved methods for classifying cranes from selected measurements. We found that the three named subspecies are in fact morphologically distinct, although there is a general gradient of smaller birds breeding in the far north to larger birds breeding at more southerly latitudes. We were not able to find better ways of identifying subspecies; in particular we could not find a reliable method that did not require knowledge of the sex of an individual crane.

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Key words: Grus canadensis, morphology, sandhill crane, taxonomy.

Migratory sandhill cranes (Grus canadensis) breed over an extensive area from the northern contiguous United States, Canada, Alaska, and northeastern Siberia. Three migratory subspecies are generally recognized, based on differences in morphology and plumage (Johnsgard 1983). The lesser sandhill crane (Grus canadensis canadensis), the most abundant subspecies, is distributed across the northernmost portions of the breeding range. The greater sandhill crane (G. c. tabida), which originally bred through much of southern Canada and the northern contiguous United States, declined in abundance and distribution but now has recovered in Michigan, Wisconsin, Minnesota, southern Ontario, and the northern Rockies; in addition, smaller populations exist in the Pacific Flyway. The Canadian sandhill crane (G. c. rowani) breeds in interior Canada (Walkinshaw 1965, Aldrich 1979, Meine and Archibald 1996), although the extent of its breeding range is uncertain. Biologists primarily use morphological measurements and sex to discriminate among these subspecies; however, there is considerable overlap in measurements between putative subspecies (Johnson and Stewart 1973, Tacha et al. 1985).

What has been termed the midcontinental “population” of sandhill cranes includes segments of all three migratory subspecies. Almost 500,000 cranes that breed in Canada from Manitoba and Nunavut, Alaska, and northeastern Siberia (Johnsgard 1983, Sharp and Vogel 1992) migrate through the Great Plains and winter in south-central United States and northern and central Mexico.

Management of midcontinental sandhill cranes provides valuable opportunities for recreational crane-watching (e.g., Lingle 1992) and hunting in Canada and the United States. Interest in crane hunting has heightened; the harvest of cranes has increased by 3.4% per year over the past 18 years (1982-2000), about twice the rate of population growth (1.6% per year) (Sharp et al. 2002). During 1990-2000 an average of 18,486 midcontinental sandhill cranes were harvested in the United States (Sharp et al. 2002). Because sandhill cranes have delayed sexual maturity and the lowest known recruitment rates of any hunted avian species in North America (Drewien et al. 1995), hunted populations must be carefully managed. Current management is based in part on information gained by the identification of subspecies within the harvest; that information has been used to try to limit the harvest of tabida, which has been in recovery throughout much of its breeding range. This strategy is based on the assumption that different subspecies, as identified by morphological measurements, derive from different portions of the breeding range. Some states assess the racial composition of harvested cranes by recording morphological measurements—lengths of primary wing chord, tarsus, and culmen—on a sample of the harvested cranes (e.g., Kendall et al. 1997, Schmitt and Hale 1997). Because females and males differ in measurements, the sex of each adult bird also must be determined, which is sometimes difficult in field situations because it requires examination of internal reproductive organs.

Oberholser (1921) noted that morphological measurements from some crane specimens were intermediate between those of tabida and canadensis, which at that time were considered two distinct species. Walkinshaw (1949:64) identified an area in central Canada where breeding cranes were intermediate in size between tabida and canadensis. Later, Walkinshaw (1965) described this intermediate subspecies and named it rowani. Walkinshaw (1965) based his definition of rowani on measurements and plumage coloration on 10 birds (7 males and 3 females) collected in Saskatchewan, Alberta, and southern Mac-

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kenzie District. Johnson and Stewart (1973) reexamined the measurements of those 10 cranes and determined that each of them (not just their average) was statistically distinct from both tabida and canadensis in terms of wing chord, tarsus length, and exposed culmen length.

Other researchers have questioned the validity of these subspecies, particularly the rowani subspecies. Stephen (1967) contended that attempts to differentiate subspecies by the criteria used at that time were not warranted, largely because measurements of adult males appeared to follow a normal distribution, which he erroneously concluded indicated a single population. Tacha et al. (1985) argued against the subspecies notion because migrant and wintering cranes did not form three distinct morphometric groups. Tacha et al. (1985) did not form that conclusion on the basis of breeding birds, however, which is essential for identifying subspecies. They also reported evident pairing between sandhill cranes presumably of different subspecies. They claimed that populations with a high degree of genetic interchange would be unlikely to persist as distinct subspecies.

Measurements of midcontinental sandhill cranes are consistent with a cline in size, in which the largest cranes (tabida) are in the southernmost areas and the smallest (canadensis) are in the northernmost areas (Walkinshaw 1949). Also, information on the morphology and distribution of rowani, the intermediate-sized species whose breeding range falls between canadensis and tabida, is very limited. Measurements from these birds have been the primary basis of studies assessing subspecies composition in various areas and seasons and in harvest assessments (e.g., Buller 1967, Stephen 1967, Lumsden 1971, Aldrich 1979, Guthery and Lewis 1979, Kendall et al. 1997). Further, recent studies of sandhill crane genetics indicated differences in mitochondrial DNA only between canadensis and 4 other subspecies (Rhymer et al. 2001) and a suggestion that rowani is a mixture or hybrid of tabida and canadensis (Petersen et al. 2003). Similarly, Jones (2003) examined microsatellite nuclear DNA and found no patterns concordant with a separation of the rowani subspecies.

Considerations about the validity of rowani as a subspecies, particularly the limited number of specimens from which the morphology has been described, and the difficulty in determining subspecies in operational surveys of hunter-shot birds led to this study. Our objectives were 1) to evaluate the subspecies designation of midcontinental sandhill cranes, particularly with respect to rowani, based on morphological characteristics; and 2) to develop improved classification methods for determining subspecies from selected measurements of hunter-shot cranes. We discuss our findings relative to recent results from genetic studies and the significance for the management of midcontinental sandhill cranes.

METHODS

We obtained measurements of sandhill cranes from several sources: 1) original notes provided to DHJ by L. H. Walkinshaw on numerous crane specimens from throughout North America that Walkinshaw had measured, which were used by Johnson and Stewart (1973); 2) additional museum specimens that had been collected in Alaska, British Columbia, Oregon, Alberta, and Saskatchewan; 3) cranes collected specifically for this study in the Northwest Territories, Alberta, Saskatchewan, Manitoba, Ontario, and Minnesota; 4) measurements of live cranes in Wisconsin under study by the International Crane Foundation; and 5) cranes measured along Lake Huron in Ontario (Urbanek 1988). All birds included in this study were of known sex and known breeding locality (except for a few migrant birds recorded where only tabida occur). It is possible, nonetheless, that some of the birds were non-breeders and might have wandered outside of the normal breeding range of their subspecies.

We tentatively assigned cranes to subspecies based on their breeding locality and the presumed breeding ranges of the 3 subspecies (e.g., Lumsden 1971, Aldrich 1979, Johnsgard 1983). That is, cranes breeding in the lower 48 states of the U.S. or in southern British Columbia were assigned to the tabida subspecies (Fig. 1). Birds from the central or northern parts of the Prairie Provinces, southern Northwest Territories, and central or northern Ontario were deemed rowani. Cranes from coastal Alaska and the northern portions of Nunavut, Northwest Territories, and British Columbia were assigned to the canadensis subspecies. Four cranes collected recently from extreme southeastern Manitoba were initially left unclassified.

We used 3 standard morphological measurements (recorded to the nearest 0.1 mm): culmen post-nares (from bill tip to proximal end of nares), total tarsus length (diagonal length from the most medial condyle of the tarsometatarsus where it articulates with the mid-toe to the rounded exterior portion of the distal condyles of the tibiotarsus; Dzubin and Cooch 1992), and wing chord (from carpal joint to tip of longest unflattened primary).

For some specimens, recorded culmen measurements were from the posterior of the nares; for others the entire exposed culmen length (from where integument meets the horny portion of the mandible) had been measured. Likewise there was some inconsistency in tarsus length measurements, sometimes involving the diagonal tarsus, other times involving the total tarsus. To obtain a complete set of comparable measurements, we developed conversion ratios. These values were determined from specimens on which both types of measurements had been recorded. To estimate culmen post nares length from exposed culmen length, we multiplied the exposed culmen length by the median ratio of culmen post nares length to exposed culmen length (0.767; mean = 0.769, SD = 0.035, N = 101). Diagonal tarsus measurements were obtained from total tarsus measurements by multiplying the latter quantity by the median ratio between the 2 types (0.919; mean = 0.919, SD = 0.022, N = 69).

To determine if certain linear combinations of the morpho-
logical measurements usefully summarized the data, we performed principal component analysis on the 3 measurements. We examined differences in morphological measurements among putative subspecies by estimating orthogonal contrasts between means of canadensis and rowani, and between rowani and tabida. These comparisons were made for both the original measurements and the principal components with SAS Proc GLM (SAS Institute Inc. 1989).

We performed linear discriminant function analysis to determine if the 3 morphological measurements could reliably distinguish the 3 subspecies. Analyses were performed separately for each sex with SAS Proc DISCRIM (SAS Institute Inc. 1989). To estimate the misclassification rate, we used a cross-validation approach. That is, we classified each crane using discriminant functions computed from the data set, excluding the individual crane being classified, and determined how many cranes were assigned to the wrong subspecies. This leaving-one-out method is the most rigorous way to estimate the error rate (Lachenbruch 1975). Discriminant function analysis also generates for each crane “probabilities” that the crane is a member of each of the 3 subspecies.

We further considered the feasibility of classifying birds when certain information is lacking. We performed discriminant function analysis for pooled birds, without distinguishing sex. We also conducted analyses with subsets of one or 2 of the 3 available morphological measurements. We did these latter analyses both with and without using knowledge of the sex of each bird.

RESULTS

We had measurements of 240 sandhill cranes, including 65 presumed canadensis, 49 rowani, 122 tabida (Table 1), and the 4 cranes with undetermined subspecies. The 3 measurements were fairly strongly correlated; among all birds, correlation coefficients were 0.80 between culmen length and tarsus length,
0.67 between culmen length and wing chord, and 0.77 between
tarsus length and wing chord. The principal component analy-
sis yielded one principal component (PC1) that explained 83%
of the variation in the three measurements. It reflected overall
body size, with similar coefficients for each measurement: 0.60
for tarsus length, 0.57 for culmen length, and 0.56 for wing
chord. When we grouped the PC1 values (by sex) into deciles
(e.g., smallest 10%, next-smallest 10%, etc.), we found that
larger birds were found mostly in the lower 48 states, smallest
birds were in northern Alaska, and birds of intermediate size were found in central
Canada. The large numbers indicate median values of large samples of birds from Wisconsin (N = 64) and lower Michigan (N = 17).

Morphometric measurements, as well as the first principal
component, varied among subspecies and between sexes (Table
1). Contrasts comparing canadensis with rowani, and rowani
with tabida indicated that rowani was closer in average mea-
surements to tabida than to canadensis for culmen length and
tarsus length, but closer to canadensis for wing chord (Tables 1
and 2).

Discriminant functions reflected the same patterns, with
greater differences between canadensis and rowani for culmen
length and tarsus length, and between rowani and tabida for
wing chord (Appendix). Discriminant function analysis as-
signed most birds to their putative subspecies (Table 3). All
(63) canadensis were correctly classified. Two of the 46 (4.3%)
Table 1. Means, standard deviations, minimums, and maximums of morphological measurements (mm) of sandhill cranes, including the first principal component, by sex and putative subspecies.

<table>
<thead>
<tr>
<th>Variable</th>
<th>canadensis</th>
<th>rowani</th>
<th>tabida</th>
<th>canadensis</th>
<th>rowani</th>
<th>tabida</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culmen length</td>
<td>68.9</td>
<td>84.5</td>
<td>94.0</td>
<td>70.9</td>
<td>90.7</td>
<td>100.5</td>
</tr>
<tr>
<td>SD</td>
<td>4.0</td>
<td>5.7</td>
<td>8.9</td>
<td>4.7</td>
<td>5.8</td>
<td>10.2</td>
</tr>
<tr>
<td>Minimum, maximum</td>
<td>63, 78</td>
<td>73, 98</td>
<td>76, 113</td>
<td>60, 78</td>
<td>76, 99</td>
<td>82, 120</td>
</tr>
<tr>
<td>Tarsus length</td>
<td>174.5</td>
<td>212.9</td>
<td>238.5</td>
<td>187.8</td>
<td>227.6</td>
<td>251.8</td>
</tr>
<tr>
<td>SD</td>
<td>13.8</td>
<td>12.2</td>
<td>11.3</td>
<td>14.4</td>
<td>8.9</td>
<td>13.6</td>
</tr>
<tr>
<td>Minimum, maximum</td>
<td>141, 198</td>
<td>189, 233</td>
<td>221, 278</td>
<td>158, 214</td>
<td>204, 243</td>
<td>226, 289</td>
</tr>
<tr>
<td>Wing chord</td>
<td>444.7</td>
<td>469.8</td>
<td>511.9</td>
<td>469.5</td>
<td>494.1</td>
<td>535.6</td>
</tr>
<tr>
<td>SD</td>
<td>19.9</td>
<td>16.6</td>
<td>20.0</td>
<td>21.7</td>
<td>16.3</td>
<td>19.1</td>
</tr>
<tr>
<td>Minimum, maximum</td>
<td>420, 490</td>
<td>435, 500</td>
<td>478, 575</td>
<td>418, 505</td>
<td>455, 524</td>
<td>490, 575</td>
</tr>
<tr>
<td>PC1</td>
<td>-2.58</td>
<td>-0.78</td>
<td>0.76</td>
<td>-1.82</td>
<td>0.17</td>
<td>1.68</td>
</tr>
<tr>
<td>SD</td>
<td>0.56</td>
<td>0.51</td>
<td>0.60</td>
<td>0.60</td>
<td>0.44</td>
<td>0.58</td>
</tr>
<tr>
<td>Minimum, maximum</td>
<td>-3.66, 1.68</td>
<td>-1.55, 0.10</td>
<td>-0.29, 2.47</td>
<td>-3.32, -0.90</td>
<td>-0.95, 0.96</td>
<td>0.19, 3.11</td>
</tr>
<tr>
<td>N</td>
<td>21</td>
<td>21</td>
<td>60</td>
<td>44</td>
<td>28</td>
<td>62</td>
</tr>
</tbody>
</table>
presumed *rowani* specimens were assigned to *tabida*. Eight of the 113 (7.1%) putative *tabida* specimens were classified as *rowani*. No *rowani* or *tabida* were assigned to *canadensis*. Overall, then, if cranes were equally likely to belong to any of the 3 subspecies and either sex, the discriminant functions would misclassify about 3.8% of them.

For 8 of the 9 misclassified cranes, the classification probabilities for the presumed subspecies and for the assigned subspecies were very close; that is, the cranes were nearly intermediate between averages for the two subspecies. The single misclassified specimen for which assignment probabilities were not close, and 4 other misclassified birds, were from Wisconsin; these were measured as live birds and were classified as *rowani* rather than *tabida*. Two other misclassified cranes were from Michigan and Ohio, presumably *tabida* but classified as *rowani*. Two putative *rowani*, both from central Saskatchewan, were classified as *tabida*.

Of the 4 cranes from extreme southeastern Manitoba, to which we did not initially assign a subspecies, two were classified as *tabida* and two as *rowani*. These cranes did not appear to be intermediate in size between the 2 subspecies; the discriminant function assigned each of them with posterior “probabilities” between 0.96 and 0.98.

When we treated sex as unknown and tried to classify cranes into subspecies based on the three morphological measurements, error rates increased dramatically (Table 4). A few (3 of 63) *canadensis*, all males, were called *rowani*. Two (females) of 46 *rowani* were classified as *canadensis* and 4 (males) were grouped with *tabida*. Nineteen (18 females, 1 male) of 113 *tabida* were misclassified as *rowani*. The overall error rate tripled, to 11.5%, versus 3.8% when sex-specific discriminant functions were used.

Discriminant functions based on subsets of the 3 morphological measurements tended to have higher error rates than those based on the full set, except that tarsus length and wing chord performed as well as the full set (Table 5). Tarsus length was the single best discriminating variable, but error rates based on only that measurement were much higher than error rates based on two or more measurements.

**DISCUSSION**

We found that the 3 putative subspecies of midcontinental sandhill cranes are morphologically distinct, in that specimens from breeding ranges described for the subspecies are distinguishable. The *rowani* subspecies, which is intermediate both in terms of breeding latitude (approximately) and in morphological measurements, differed most markedly from *tabida* in wing chord, and from *canadensis* in culmen length and tarsus length. Although subspecies appear distinct, all measures of body size demonstrate a size gradient, with larger birds found at more southern latitudes and smaller birds at more northern latitudes.
latitudes. The trend toward smaller body size in the north is similar to that found among Canada geese (*Branta canadensis*; Bellrose 1980, Dunn and MacInnes 1987), a species that also breeds from southern latitudes to the Arctic.

The cranes from southern British Columbia, initially assigned to *tabida*, indeed turned out to be large and ultimately were assigned to *tabida* by the discriminant functions. Those birds had been collected between 1947 and 1964. Recent observations of sandhill cranes from that area have generally been consistent with measurements of *rowani*, although uncertainty is considerable because the sex of individual birds was not known (Ivey et al. 2004). Both *tabida* and *rowani* have been recorded in southwestern British Columbia (Ivey et al. 2004), so the assignment of *tabida* to the cranes included in our analysis is sensible.

It seems reasonable to speculate that the breeding range of sandhill cranes was once contiguous, but that, possibly due to reductions in numbers, breeding populations became constricted and fragmented into more-or-less discrete ranges, including those inhabited by non-migratory birds in Mississippi, Florida, and Cuba. As populations have grown in recent decades, breeding ranges have expanded dramatically. Conceivably, areas that once separated breeding ranges have become occupied, and the distinctions between subspecies are becoming blurred.

This conjecture is consistent with the 4 cranes reported from southeastern Manitoba, which included 2 evident *tabida* and 2 evident *rowani*. The occurrence of cranes classified as *rowani* or *tabida* outside of their expected ranges in this study and inconsistencies in classification to subspecies between genetic and morphological approaches (Glenn et al. 2002) is consistent with the possibility of interbreeding across subspecies (Tacha et al. 1985).

Regardless of the genetic distinctiveness of what have been called subspecies, the populations of birds differ in a variety of ways, including morphology (Aldrich 1979, this study), migrational timing and pathways (e.g., Johnson and Stewart 1973), rates of development (Baldwin 1977), onset of homeothermy (Baldwin 1977), and other characteristics. Further, the distributions (this study) of the 3 subspecies indicate that generally they breed in different areas: most *canadensis* breed in the arctic regions of Alaska and northern Canada; *rowani* in subarctic, boreal, and parkland ecoregions of Canada; and *tabida* in various regions of the United States and southernmost Canada. Indeed, it is not necessary to accept the division of sandhill cranes into the 3 subspecies in order to recognize the distinctiveness of the birds based on body size and the consistency of the association between body size and breeding area (Fig. 2). Hence, it may be desirable to manage these regional breeding populations individually.

For our second objective, we were not able to develop more effective methods for classifying cranes into the 3 subspecies. The discriminant functions we developed performed well, nonetheless, with a 3.8% error rate. We did find that, in our samples, discriminant functions that used only tarsus and

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**Table 4.** When the sex of individual cranes was treated as unknown, more birds were misclassified by linear discriminant analysis.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Classified from</th>
<th><em>canadensis</em></th>
<th><em>rowani</em></th>
<th><em>tabida</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td><em>canadensis</em></td>
<td>21</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>rowani</em></td>
<td>2</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>tabida</em></td>
<td>0</td>
<td>18</td>
<td>37</td>
</tr>
<tr>
<td>Male</td>
<td><em>canadensis</em></td>
<td>39</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>rowani</em></td>
<td>0</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td><em>tabida</em></td>
<td>0</td>
<td>1</td>
<td>57</td>
</tr>
</tbody>
</table>

**Table 5.** Error rates (estimated probabilities of misclassification, as percentages) for discriminant functions based on various sets of morphological measurements, with or without sex known.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Classified from</th>
<th><em>canadensis</em></th>
<th><em>rowani</em></th>
<th><em>tabida</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td><em>canadensis</em></td>
<td>21</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>rowani</em></td>
<td>2</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>tabida</em></td>
<td>0</td>
<td>18</td>
<td>37</td>
</tr>
<tr>
<td>Male</td>
<td><em>canadensis</em></td>
<td>39</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><em>rowani</em></td>
<td>0</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td><em>tabida</em></td>
<td>0</td>
<td>1</td>
<td>57</td>
</tr>
</tbody>
</table>
wing chord, along with sex, performed as well as those that also used culmen length. Because culmen length is readily measured, however, we recommend that it be included. Wing chord has traditionally been used as a measure of wing length, but it is affected by wear of the longest primaries, which likely contributed to its high error rate even when sex was known. A more precise measure of wing size, e.g., midwing (measured ventrally from proximal end of ulna to distal end of radius, proximal to spur; Rasmussen et al. 2001) could be considered as an alternative to wing chord.

Although it would be desirable to have effective classification rules that do not require knowledge of the sex of individual birds, we found that such discriminant functions performed much more poorly than those that used knowledge of the sex. Error rates tripled for the most effective discriminant functions when information about sex was not used. Nesbitt et al. (1992) also found that determinations of subspecies when sex was unknown were not accurate.

Whereas knowledge of the sex of a crane is valuable for ascertaining its subspecies, it may be reasonable to consider the subspecific composition of groups of birds, rather than individuals. That is, it may be feasible to estimate the subspecific composition of a group by recording fewer measurements but using larger samples of birds.

ACKNOWLEDGMENTS

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Measurements of specimens in museums were provided by Christine Adkins, Cowan Vertebrate Museum, University of British Columbia; Bruce McGilvery, Provincial Museum of Alberta; Keith Roney, Royal Saskatchewan Museum; Gary Shugart, Slater Museum of Natural History, University of Puget Sound; and Fred Sibley, Peabody Museum of Natural History, Yale University.

Betty R. Euliss assisted this project in several ways. We are grateful to Rod C. Drewien, Gary L. Ivey, Ken L. Jones, Stanley C. Kohn, Gary L. Krapu, Marilyn G. Spalding, and Stephen A. Nesbitt for comments on earlier drafts of this report.

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### Appendix

<table>
<thead>
<tr>
<th>Variable</th>
<th>Females</th>
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<th></th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>canadensis</td>
<td>rowani</td>
<td>tabida</td>
<td>canadensis</td>
</tr>
<tr>
<td>Intercept</td>
<td>-325.05</td>
<td>-398.25</td>
<td>-481.18</td>
<td>-391.98</td>
</tr>
<tr>
<td>Culmen</td>
<td>0.57</td>
<td>0.77</td>
<td>0.87</td>
<td>0.95</td>
</tr>
<tr>
<td>Tarsus</td>
<td>0.81</td>
<td>1.07</td>
<td>1.20</td>
<td>0.81</td>
</tr>
<tr>
<td>Wing</td>
<td>1.06</td>
<td>1.07</td>
<td>1.16</td>
<td>1.20</td>
</tr>
</tbody>
</table>
IMPACT OF MANAGEMENT CHANGES AT AN AUTUMN GREATER SANDHILL CRANE STAGING AREA IN OREGON

CARROL D. LITTLEFIELD1, Malheur National Wildlife Refuge, 36391 Sodhouse Lane, Princeton, OR 97721 USA

Abstract: Malheur National Wildlife Refuge, Oregon was the most important autumn staging area for greater sandhill cranes (Grus canadensis tabida) in the northwest Pacific coastal states. During 1983-88, changes in management including increases in human disturbance and habitat alterations resulted in significant declines in autumn crane use. Compared with the period 1975-82, mean annual autumn crane peak numbers declined from 2,454 to 1,352, whereas mean biweekly numbers declined from 791 to 353. Management changes included roost site drying and flooding of a primary feeding area; disturbance factors included cattle herding through a loafing site and dump trucks traveling through a primary feeding area. Although Malheur was a traditional autumn staging area for greater sandhill cranes for at least 5 decades, management changes had contributed to greatly reduced use of the refuge staging area by 1988.

Keywords: autumn staging, greater sandhill crane, Grus canadensis tabida, human disturbance, Malheur National Wildlife Refuge, management changes, Oregon

At least since 1938 and through the early 1980s, Malheur National Wildlife Refuge (hereafter Malheur), Harney County, in southeastern Oregon, was the most important autumn greater sandhill crane (Grus canadensis tabida, hereafter crane) staging area in the northwestern Pacific coastal states (Littlefield 1992). Improved farming practices contributed to increasing and more consistent autumn use between 1975-82 (Littlefield 1986). However, beginning in 1983 and continuing through 1988, incidental changes in management practices and episodes of increased human disturbance occurred on autumn crane staging sites. This provided an opportunity to compare peak autumn crane numbers, biweekly numbers, and use-days for years with apparent excessive disruptions (1983-88, disruptive period), to years when cranes were minimally disturbed and autumn staging areas were managed specifically for their benefit (1975-82, non-disruptive period).

STUDY AREA AND METHODS

On the ±75,000 ha Malheur, some 325 ha in 2 to 5 grain fields were planted annually since c.1970 to barley with minor plantings of wheat and oats. These fields and nearby loafing and roosting sites were used extensively by cranes in autumn (Littlefield 1986). The 2 principal crop areas were near Buena Vista Substation (43°04′N, 118°54′W), about 27 km south of Malheur headquarters (±51 km SSE of Burns), and near Knox Pond (42°54′N, 118°54′W), 13 km NNE of Frenchglen at the southern end of the Refuge. Most autumn crane feeding use was at East Grain Camp near Buena Vista, whereas Knox Pond was a secondary use-area. A detailed description of Malheur is provided in Littlefield (1990). From 1975-88 cranes were counted weekly from mid-July until all cranes had migrated; annual peak numbers, mean biweekly numbers, and total annual crane use-days were used for data analysis (a crane use-day was 1 crane using the area for 1 day). Use-days were determined by the number of cranes present on weekly counts multiplied by 7 days; total annual use-days were the summation of weekly use-day subtotals. Counts were from a vehicle using a 20x spotting-scope and 7x binoculars. Birds were counted annually during 1975-88 as they fed in grain fields or as flocks flew between croplands and wetland roost sites. Counts were primarily in late afternoon/early evening but included several morning counts. During 1983-88, weekly aerial waterfowl surveys and periodic ground searches confirmed that cranes were not using other refuge locations or private agricultural areas within the county. Human disturbance observations were chance encounters, and all disturbances were not detected.

For purposes of analysis, management activities at Malheur that impacted numbers of autumn staging cranes were separated into 2 periods: 1) 1975-82 when activities were non-disruptive and encouraged fall staging of cranes, and 2) 1983-88 when activities were less favorable and disrupted staging cranes. Two-tailed t-tests were used to compare differences for both mean autumn peak and biweekly mean numbers between the disruptive period when management was less favorable for cranes (1983-88) and the non-disruptive period when management was more favorable for cranes (1975-82). Autumn crane use-days were compared by regression analysis.

RESULTS

Autumn Greater Sandhill Crane Numbers

Mean autumn peak numbers of cranes using Malheur dur-
ing 1975-82 was 2,454 (SD = 529), and for 1983-88 was 1,352 (SD = 958). Peak numbers during 1975-82 were higher than for 1983-88 (t = 2.54, 12 df, p < 0.05; Table 1). However, it was 2 years before a dramatic decline in crane numbers began in 1985 when the peak dropped to 1,292, 650 in 1986, with only 319 during the drought year of 1988 (Table 2). Annual peaks for 1975-82 occurred during October (6 yrs) and November (2 yrs), whereas during 1983-88 peak numbers were reached in August (1 yr), September (1 yr), and October (4 yrs).

Annual biweekly mean crane numbers showed a similar trend, declining from 784 (SD = 215.3) during 1975-82 to 353 (SD = 201.7) during 1983-88. Significantly fewer cranes annually used Malheur grain fields in 1983-88 than in 1975-82 (t = 3.52, 12 df, p < 0.01). Before 1983, 395 to 3,408 cranes remained into November (Table 1), but after 1982 cranes had usually left by mid-October (Table 2).

Autumn Greater Sandhill Crane Use-days

Malheur autumn crane use-days also significantly declined at Malheur between 1975 and 1988 (Rs = 0.707, p < 0.02). Mean annual use-days were 120,683 for 1975-82, but as human disturbance increased and staging habitat management was less favorable, autumn use declined after 1982 and accelerated after 1984 (Fig. 1). In 1983 and 1984, mean autumn use-days were 71,182 and for 1985 through 1988 only 29,024. The lowest recorded use-days were 12,163 in 1988.

Management Changes and Recorded Disturbance

Observed human disturbance and management activities which appeared to negatively impact autumn crane use at Malheur during 1983-88 were:

• 1983 - autumn dike repair with heavy equipment adjacent to East Grain Camp apparently caused many cranes to depart before mid-October.

• 1984 - roost sites were dry by mid-October and most cranes left shortly thereafter. On 13 October, 2,720 cranes were at Malheur, but numbers declined to 313 by 18 October. The primary loafing site near East Grain Camp was not flooded, although water was available.

• 1985 - cattle were herded through the primary loafing site on 4 October, and 177 cranes immediately initiated migratory behavior and departed in a southwesterly direction (C. D. Littlefield, unpublished data). Dump trucks were continuously driven 5-days per week through the East Grain Camp feeding site during the peak crane staging period, while an adjacent loafing site was not flooded until after most cranes had left; only 11 cranes remained after 10 October.

• 1986 - autumn use was further reduced as cranes responded adversely to barley stubble flooding, eliminating East Grain Camp as a feeding site because underwater waste grain is

Table 1. Biweekly peak number of greater sandhill cranes staging at Malheur National Wildlife Refuge, Oregon staging area, summer and fall 1975-1982 when management activities were favorable (non-disruptive period) for cranes. Annual peak counts in bold.

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Table 2. Biweekly peak number of greater sandhill cranes staging at Malheur National Wildlife Refuge, Oregon, summer-fall 1983-1988, when management activities were less favorable for cranes (disruptive period). Annual peak counts in bold.

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Fig. 1. Greater sandhill crane autumn use-days during 1975-88 on Malheur National Wildlife Refuge, Oregon (non-disruptive period 1975-82; disruptive period 1983-88).
generally inaccessible to cranes (Littlefield 2002). The primary loafing site received no water by 10 October. Cranes were observed migrating over Malheur in September and October, but few stopped.

- 1987 - East Grain Camp barley stubble was again flooded, resulting in the loss of the primary feeding site; the Knox Pond roost site remained dry during autumn.
- 1988 - little barley production occurred due to drought. Also, although water was available, none was diverted into loafing and roosting sites.

DISCUSSION

Greater sandhill cranes summering in the western United States traditionally use autumn staging areas before migrating to wintering grounds in the southwestern United States and northern Mexico (Drewien and Bizeau 1974, Lewis 1977, Littlefield 1986, 1992, Drewien et al. 1999). In the northwestern Pacific coastal states, Malheur had been a traditional autumn staging area for cranes during at least 5 decades (Littlefield 1986). Before 1983, autumn staging sites at Malheur were managed in a relatively undisturbed condition to encourage crane use, and refuge maintenance activities were delayed until after cranes had migrated. Shallow and stable water levels were maintained in ponds near grain fields to provide autumn roosting sites. In addition, 1-2 adjoining mowed meadows were shallowly flooded for mid-day loafing. Autumn crane departures were primarily related to availability of grain and/or climatic factors, and most normally migrated in late October and early November (Littlefield 1992). However, after autumn 1982, crane staging sites were modified by changes in management strategies, and by 1988 many cranes were leaving in September, occasionally in August, or migrating over in September and October without stopping.

The Central Valley Population of greater sandhill cranes, which includes birds summering in Oregon, declined at a few breeding locations, including Malheur during the period 1975-88, but overall the population was generally stable (Stern et al. 1987, Littlefield et al. 1994). One would not have expected such an accelerated and dramatic drop in autumn crane use at Malheur. Crane intolerance to human activity and changes in autumn habitat management had previously not been as important at Malheur as had been reported elsewhere (Lewis 1977, Perkins and Brown 1981, Drewien 1997). However, at Malheur in the mid-1980s disturbance apparently became excessive and less favorable staging habitat management resulted in a precipitous decline in crane use. Although tradition may dictate annual crane behavior and geographical use-areas, such traditions can be disrupted and finally broken if cranes are exposed to excessive disturbance and/or unfavorable habitat management practices over multiple seasons.

After well over a decade the Malheur autumn staging area has not been restored, although in some years ample and undisturbed feeding, roosting, and loafing sites have been provided (Richard Roy, Biologist, Malheur National Wildlife Refuge, Princeton, OR personal communication). Recent evidence suggests many cranes are now leaving or over-flying southeastern Oregon in September-early October, and migrating considerably earlier to their Central Valley wintering areas in California. Crane aggregations are presently reported in Central Valley winter sites in September and early October (C. D. Littlefield, unpublished data, R. Schlorff, California Department of Fish and Game, Sacramento, pers. comm.), whereas prior to the mid-1980s birds generally did not arrive in large numbers until after mid-October (C. D. Littlefield, unpublished data).

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LITERATURE CITED

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