Journal of Wildlife Diseases, 47(3), 2011, pp. 627–637

MORTALITY FACTORS AND DISEASES IN FREE-RANGING EURASIAN CRANES (*GRUS GRUS*) IN GERMANY

Jane Fanke,[1] Gudrun Wibbelt,[1] and Oliver Krone[1,2]

[1] Leibniz Institute for Zoo and Wildlife Research, Alfred-Kowalke-Str. 17, 10315 Berlin, Germany
[2] Corresponding author (email: krone@izw-berlin.de)

ABSTRACT: Detailed postmortem examinations were performed on 167 free-ranging Eurasian Cranes (*Grus grus*) from Germany, collected between September 1998 and December 2008 to evaluate causes of death and diseases. The most common causes of mortality were traumatic injuries ($n=105$, 62.9%) from collisions with power lines ($n=39$, 23.4%) and wire fences ($n=12$, 7.2%). A group of 28 Eurasian Cranes (16.8%) died from organophosphate intoxication. Predation by White-tailed Sea Eagles (*Haliaeetus albicilla*) and red foxes (*Vulpes vulpes*) occurred in four cases (2.4%). Pathologic changes due to infectious diseases were associated with *Aspergillus* spp. ($n=7$, 4.2%), endoparasites ($n=7$, 4.2%), avian poxvirus ($n=6$, 3.6%), *Mycobacterium* spp. ($n=2$, 1.2%), and adenovirus infection ($n=1$, 0.6%). A severe *Strigea* spp. infection ($n=1$, 0.6%) and a leiomyosarcoma ($n=1$, 0.6%) were newly recognized diseases in Eurasian Cranes in this study.

Key words: Collision, endoparasites, intoxication, pathology, poxvirus, trauma.

INTRODUCTION

Following legal protection and intensive wetland restorations, Eurasian Cranes (*Grus grus*) have made a rapid recovery within the past 30 yr, after hunting drastically reduced their numbers before the 20th century (Mewes et al., 2003). Currently, about 26,000 individuals constitute the Eurasian Crane population in Germany. Simultaneous surveys and censuses, by the German Crane Conservation Group, during autumn migrations, documented approximately 60,000 to 80,000 Eurasian Cranes from Scandinavia, the Baltic States, and central Europe, each staging at three main stopover sites in Germany (Prange, 2007). When thousands of Eurasian Cranes rest for weeks in the same region, the depredation potential for maize and cereal seedlings increases. To prevent Eurasian Cranes from feeding on crops, land owners try to distract birds by creating feeding sites. However, the effect of crowding on feeding sites, particularly during migration, may result in higher transmission rates of pathogens in Eurasian Cranes and other wild birds. Current conservation measures for the species include assessment of health status and identification of causes of death. In a preliminary study, Krone et al. (2003) found that flight collisions were the most common cause of mortality in Eurasian Cranes from Germany, whereas diseases seemed to be underrepresented because of limited samples. Here, we describe mortality factors in Eurasian Cranes, emphasizing the pathologic changes of infective agents and endoparasites.

MATERIALS AND METHODS

Eurasian Crane carcasses were submitted for necropsy to the Leibniz Institute for Zoo and Wildlife Research (IZW; Berlin, Germany), through a large-scale network of the German Eurasian Crane Conservation Group, and several nature conservation authorities. We summarize investigations of 167 Eurasian Cranes, collected from September 1998 through December 2008. Of those birds, 40 (24%) were alive at the time of retrieval but died ($n=21$) or had to be euthanized ($n=19$) at rehabilitation centers. Eurasian Cranes originated from northeast Germany (Brandenburg/Berlin, Germany [$n=76$, 46%], and Mecklenburg–Western Pomerania, Germany [$n=74$, 44%]), as well as central (Hesse, Germany; $n=9$, 5%), and northwest regions (Lower Saxony, Germany, $n=7$, 4%; and Schleswig-Holstein, Germany, $n=1$, 1%).

Eurasian Cranes were divided into adults ($n=60$, 36%), juveniles ($n=60$, 36%), and subadults ($n=40$, 24%) by plumage color. Juvenile head and neck feathers were brown. Subadult Eurasian Cranes (2–3 yr old) had lighter-colored heads and contour feathers

than did adult birds (≥4 yr), which had basic, grey plumage; bare, red crowns with white stripes from behind the eyes to the upper back; and black chins, foreheads, throats, anterior parts of the neck, and lores (Prange, 1989). Besides the plumage color, the presence of molted feathers and the development of the reproductive tract (gonads, oviduct) were evaluated for age group–specific characteristics. Eighty-five females (50.9%) and 76 males (45.5%) were included in this study. Advanced decomposition and scavenging precluded the identification of age for seven carcasses and sex for six.

Complete gross necropsy and microscopic examination of brain, heart, lung, liver, kidney, spleen, and intestine were performed. Samples from these organs were fixed in 4% buffered formalin, dehydrated in graded alcohols, embedded in paraffin, sectioned at 1–3 μm, and stained with hematoxylin and eosin for light microscopy. If required, tissue slides were stained with Sudan red, Prussian-blue, Ziehl-Neelsen, periodic acid–Schiff, or Grocott methenamine silver. Selected Eurasian Cranes' alimentary tract contents were sent to the Research Institute of Wildlife Ecology, University of Veterinary Medicine, Vienna, Austria, to confirm suspected zinc phosphide intoxication. Evaluation of bacterial and fungal pathogens of selected samples was performed at the IZW. Parasites isolated during necropsy were identified to genus or species level by light microscopy (10× to 100× magnification; Zeiss Axioskop, Carl Zeiss, Oberkochen, Germany) using references and keys for identification of trematodes (Yamaguti, 1959, 1971; McDonald, 1981), acanthocephales, and cestodes (Yamaguti, 1959; Spassky et al., 1971; McDonald, 1988), and nematodes (Mozgovoi, 1968; Hartwich, 1975, 1994). Selected adult specimens were collected and stored for further studies at the IZW.

Fresh tissue samples with suspected avian poxvirus infection were processed by negative staining for electron microscopy. They were homogenized with sea sand and distilled water and centrifuged at 10,000 × G for 10 min. Supernatant was allowed to adhere to 400-mesh copper grids covered with formvar, contrasted with 3% phosphor tungsten acid, and examined with a transmission electron microscope (902 A, Carl Zeiss).

The primary cause of death was identified for each Eurasian Crane from the most substantial injury or illness. Distribution of the most common causes of death among sex and age classes was evaluated with the standard two-sided χ^2 test for independence using statistical software (SPSS Base 16.0, SPSS Inc., Chicago, Illinois, USA).

RESULTS

Gross necropsies and histopathologic examinations were performed on 167 free-ranging Eurasian Cranes. Of 161 cranes that were not too decomposed to allow histopathologic examination, causes of death included trauma ($n=105$, 62.9%), zinc phosphate intoxication ($n=28$, 16.8%), infections ($n=24$, 14.4%), and predation ($n=4$, 2.4%; Tables 1 and 2).

Traumatic mortality occurred more often in the first ($n=37$, 35.2%) and second quarters ($n=29$, 27.6%) of the year than in the third ($n=20$, 19.1%) and fourth quarters ($n=19$, 18.1%; $\chi^2=10.046$, $P=0.018$). Adult Eurasian Cranes ($n=50$, 29.9%) died more frequently from trauma than did juvenile ($n=26$, 15.6%) or subadult individuals ($n=22$, 13.2%). These birds had moderate to severe injuries with various fractures, accompanied by subcutaneous and intramuscular hematomas, along the shoulder girdle, chest, or long bones. In addition, mild to severe hemorrhage was variably detected in lungs, air sacs, liver, and kidney. Electrocution at medium voltage (20 kV) power lines was associated with burn marks on feathers and skin. White-tailed Sea Eagle Crane attacks led to laceration and puncture wounds of the skin and muscles, particularly around the pectoral region. A presumed red fox (*Vulpes vulpes*) predation was associated with the absence of anterior body parts, such as head and cervical spine; multiple skin lacerations; muscular hemorrhage around the sternum; and a complete fracture of the right iliac bone. Radiographic diagnosis and subsequent dissection identified three birds with two to three lead shotgun pellets within subcutaneous and intramuscular tissues of the extremities, the sternal region, and the pectoral region.

A group of 17 juvenile and 11 subadult Eurasian Cranes, found in the Grambow

TABLE 1. Causes of mortality for (n = 143) Eurasian Cranes (*Grus grus*) from Germany that died of noninfectious causes 1998–2008. Percentages based on n=167 total Eurasian Cranes examined.

Causes of mortality	Total No. (%)	No. Male (%)	No. Female (%)	No. Adult (%)	No. Subadult (%)	No. Juvenile (%)
Trauma	105 (62.9)	47 (28.1)	52 (31.1)	50 (29.9)	22 (13.2)	26 (15.6)
Power line collision	39 (23.4)	20 (11.9)	19 (11.4)	21 (12.6)	8 (4.8)	10 (5.9)
Trauma unknown etiology[a]	33 (19.8)	12 (7.2)	15 (8.9)	12 (7.2)	7 (4.2)	8 (4.8)
Wire	12 (7.2)	4 (2.4)	8 (4.8)	6 (3.6)	3 (1.8)	3 (1.8)
Electrocution	10 (6.0)	7 (4.2)	3 (1.8)	7 (4.2)	1 (0.6)	2 (1.2)
Vehicular collision[b]	4 (2.4)	0	4 (2.4)	1 (0.6)	1 (0.6)	1 (0.6)
Sea Eagle attack	3 (1.8)	2 (1.2)	1 (0.6)	1 (0.6)	1 (0.6)	1 (0.6)
Wind turbine collision	1 (0.6)	0	1 (0.6)	1 (0.6)	0	0
Light aircraft collision	1 (0.6)	1 (0.6)	0	0	0	1 (0.6)
Red fox attack	1 (0.6)	1 (0.6)	0	0	1 (0.6)	0
Suspected illegal persecution	1 (0.6)	0	1 (0.6)	1 (0.6)	0	0
Other causes	38 (22.8)	19 (11.4)	19 (11.4)	6 (3.6)	13 (7.8)	19 (11.4)
Zinc phosphide intoxication	28 (16.8)	14 (8.4)	14 (8.4)	0	11 (6.6)	17 (10.2)
Cachexia	3 (1.8)	1 (0.6)	2 (1.2)	3 (1.8)	0	0
Leiomyosarcoma[c]	1 (0.6)	0	1 (0.6)	1 (0.6)	0	0
Hypothermia	1 (0.6)	0	1 (0.6)	0	0	1 (0.6)
Unknown	5 (3.0)	4 (2.4)	1 (0.6)	2 (1.2)	2 (1.2)	1 (0.6)
Total	143 (85.6)	66 (39.5)	71 (42.5)	56 (33.5)	35 (20.9)	45 (26.9)

[a] Six Eurasian Cranes with unknown gender and age.

[b] One Eurasian Crane with unknown age.

[c] First description in Eurasian Cranes.

moor region, near Schwerin, Germany, died from the ingestion of wheat contaminated with zinc phosphide in March 2004. Gaseous break-down products of that pesticide were detected within the Eurasian Cranes' alimentary tract. Pathologic findings were fatty degeneration of hepatocytes (all 28 Eurasian Cranes; 100%) and tubular epithelial cells of the kidneys (22/28 Eurasian Cranes; 78.6%), lung

TABLE 2. Causes of mortality for (n = 24) Eurasian Cranes (*Grus grus*) from Germany that died of infectious causes 1998–2008. Percentages based on n=167 total Eurasian Cranes examined.

Causes of mortality	Total No. (%)	No. Male (%)	No. Female (%)	No. Adult (%)	No. Subadult (%)	No. Juvenile (%)
Infection	17 (10.2)	6 (3.6)	11 (6.6)	4 (2.4)	6 (3.6)	7 (4.2)
Aspergillosis	7 (4.2)	5 (2.9)	2 (1.2)	2 (1.2)	1 (0.6)	4 (2.4)
Unknown etiology	5 (3.0)	1 (0.6)	4 (2.4)	2 (1.2)	2 (1.2)	1 (0.6)
Poxvirus infection	3 (1.8)	0	3 (1.8)	0	1 (0.6)	2 (1.2)
Mycobacteriosis	2 (1.2)	0	2 (1.2)	0	2 (1.2)	0
Parasitosis	7 (4.2)	4 (2.4)	3 (1.8)	1 (0.6)	0	6 (3.6)
P. ardeae infection[a]	3 (1.8)	1 (0.6)	2 (1.2)	0	0	3 (1.8)
Strigea spp. infection[b]	2 (1.2)	1 (0.6)	1 (0.6)	0	0	2 (1.2)
DVC[b,c]	1 (0.6)	1 (0.6)	0	0	0	1 (0.6)
Tapeworm infection	1 (0.6)	1 (0.6)	0	1 (0.6)	0	0
Total	24 (14.4)	10 (5.9)	14 (8.4)	5 (3.0)	6 (3.6)	13 (7.8)

[a] *Porrocaecum ardeae.*

[b] First description in Eurasian Cranes.

[c] Disseminated visceral coccidiosis.

TABLE 3. Numbers of Eurasian Cranes (*Grus grus*) infected and prevalence of infection (%) for parasitic infections in free-ranging Eurasian Cranes ($n=130$) from Germany. Percentages based on $n=167$ total Eurasian Cranes examined. Some cranes were infected with more than one species of parasite.

Parasite	Total No. (%)	No. Male (%)	No. Female (%)	No. Juvenile (%)	No. Subadult (%)	No. Adult (%)
Eucoleus obtusiuscula	104 (62.3)	53 (31.7)	51 (30.5)	39 (23.4)	28 (16.8)	37 (22.2)
Porrocaecum ardeae	101 (60.5)	54 (32.3)	47 (28.1)	35 (20.9)	27 (16.2)	39 (23.4)
Eimeria spp.	32 (19.2)	6 (3.6)	26 (7.8)	8 (4.8)	3 (1.8)	21 (12.6)
Strigea spp.[a]	8 (4.8)	3 (1.8)	5 (2.9)	5 (2.9)	2 (1.2)	1 (0.6)
Spirurida larvae	8 (4.8)	3 (1.8)	5 (2.9)	2 (1.2)	2 (1.2)	4 (2.4)
Cestode[b]	6 (3.6)	1 (0.6)	5 (2.9)	1 (0.6)	1 (0.6)	4 (2.4)
Tetrameres spp.	5 (2.9)	2 (1.2)	3 (1.8)	0	1 (0.6)	4 (2.4)
Prosthogonimus cuneatus	5 (2.9)	3 (1.8)	2 (1.2)	4 (2.4)	1 (0.6)	0
Echinostoma sarcinum	4 (2.4)	2 (1.2)	2 (1.2)	1 (0.6)	3 (1.8)	0
Hovorkonema variegatum[a]	3 (1.8)	2 (1.2)	1 (0.6)	0	2 (1.2)	1 (0.6)
Cyclocoeleum mutabile	2 (1.2)	2 (1.2)	0	0	0	2 (1.2)
Gruitaenia lattissima	1 (0.6)	1 (0.6)	0	0	0	1 (0.6)
Orchipedum formosum	1 (0.6)	0	1 (0.6)	0	0	1 (0.6)
Dispharynx nasuta[a]	1 (0.6)	1 (0.6)	0	1 (0.6)	0	0
Centrorhynchus spp.[a]	1 (0.6)	0	1 (0.6)	1 (0.6)	0	0
Total	130 (77.8)	66 (39.5)	64 (38.3)	43 (25.7)	34 (20.4)	53 (31.7)

[a] First records.

[b] No differentiation.

edema (25/28; 89.3%), and marked congestion in several organs, including kidneys (all 28; 100%), spleen (27/28; 96.4%), liver (25/28; 89.3%), and lungs (24/28; 85.7%), assumed to be associated with shock.

Juvenile Eurasian Cranes ($n=13$, 7.8%) died more often from infectious diseases (Table 2) than did adult (2.4%) or subadult (3.6%) Eurasian Cranes ($\chi^2=16.082$, $P=0.041$). Multiple granulomas were observed within lung and air sacs ($n=11$, 6.6%) from fungal pathogens, including *Aspergillus fumigatus* and *Mucor* spp. Three birds had multiple granulomas with intralesional, acid-fast coccoid rods in the liver, spleen, kidney, and gastrointestinal tract. In two cases, the severity of the granulomatous disease suggested mycobacteriosis as the primary cause of death, whereas another infected bird died because of a collision with a power line. Thirteen of the 167 Eurasian Cranes (7.8%) had multiple granulomas with encapsulated endoparasite stages within the mucosal layer of the intestine. In other cases, necrotic foci were seen within the liver ($n=8$, 4.8%), spleen ($n=2$, 1.2%), kidneys ($n=1$, 0.6%), and heart tissue ($n=1$, 0.6%) secondary to systemic bacterial infections of unspecified etiology.

Gastrointestinal parasites were present in 130 Eurasian Cranes (77.8%; Table 3). The most frequent parasites were *Eucoleus obtusiuscula*, *Porrocaecum ardeae*, and *Eimeria* spp. Some parasites were newly detected in Eurasian Cranes, such as *Strigea* spp., *Dispharynx nasuta*, and *Centrorhynchus* spp. Coccidian parasites were identified as round oocysts of *Eimeria reichenowi* from the mucosal layer of the small intestine and cecum. Ascarid nematodes were isolated from the anterior parts of the intestine and identified as *P. ardeae* by its body length, shape, and size of the lips and intestinal cecum (described by Hartwich, 1975). Because of severe infection with these nematodes, three Eurasian Cranes (1.8%) died from intestinal perforation and resulting septicemia, whereas other infected Eurasian Cranes had no apparent observable pathologic lesions. Capillarid nematodes (*E. obtusiuscula*) parasitized the mucosal layer of the

gizzard below the koilin layer without grossly visible lesions. *Tetrameres* spp. nematodes were isolated from the mucosal layer but did not cause macroscopic lesions. Spirurida larvae were encapsulated in the mucosal layer of the small intestine. Three Eurasian Cranes (1.8%) had mild tracheal infections (one to three nematodes) with *Hovorkonema variegatum*. Twenty-two nematodes (*Dispharynx nasuta*) were found in the proventriculus of a juvenile Eurasian Crane.

A heavy infection with the trematode *Strigea* sp. caused severe enteritis in two juvenile Eurasian Cranes. In both cases, multiple encapsulated metacercaria were observed in connective tissues. One of these Eurasian Cranes also had a disseminated visceral coccidiosis (DVC), with multiple coccidian development stages (schizonts and meronts) in the liver and spleen, as well as single coccidian structures in the kidney.

A severe tapeworm infection (11 tapeworms) caused intestinal obstruction and led to fatal emaciation in one Eurasian Crane, whereas six other infected Eurasian Cranes (3.6%) had mild infections and no obvious associated lesions. In one case, a tapeworm was identified as *Gruitaenia lattissima* (Table 3). Two juvenile Eurasian Cranes (1.2%) had systemic coccidial infections with multiple white foci in the liver, congestion of the lung and liver, and gastroenteritis as major macroscopic lesions. One Eurasian Crane died from systemic coccidial infection. The histopathologic findings were histiocytic to necrotizing inflammation of the liver and spleen in the two birds.

In six Eurasian Cranes (3.8%), avian poxvirus infection induced cauliflower-like crusty epidermal proliferations with typical microscopic hyperkeratosis and eosinophilic intracytoplasmic inclusion bodies. These poxvirus lesions occurred at the upper beak, around the eyes and were on the legs, mainly found around the intertarsal joints. Transmission electron microscopy showed multiple poxvirus particles from such skin lesions. A single adult female Eurasian Crane had as a light microscopy finding of numerous large inclusion bodies within the nuclei of most epithelial cells of the renal collecting tubules. Ultrathin sections of the kidney examined by electron microscopy revealed hexagonal, 70–74-nm-diameter adenovirus particles. However, a fatal leiomyosarcoma caused the death in that bird. The main tumor was located in the subcutaneous tissue of the left elbow and had metastasized to the lungs, where three firm, pale-yellow nodules, 3–5 cm in diameter, were found (Fig. 1). This is the first case, to our knowledge, of leiomyosarcoma reported in Eurasian Cranes.

Further histopathologic findings included follicular hyperplasia of the spleen in 14 of 24 Eurasian Cranes (58.3%) that died due to infections and in 55 of 105 (52.4%) cases of traumatic death. Multiple marked follicular aggregations of lymphocytes within the liver, particularly around portal veins, were noted in 16 juvenile Eurasian Cranes (9.6% of the 167), five adults (2.9%), and two subadults (1.2%). Multifocal clusters of iron storage were present in 120 of the 167 individuals (71.9%). Iron deposits were mainly found within hepatocytes and Kupffer cells ($n=100$, 59.9%); siderocytes occurred in the spleen in 95 individuals (56.9%), and 29 Eurasian Cranes (17.4%) had iron stored in renal tubular epithelium.

Pulmonary anthracosis was found in 24 of the 167 Eurasian Cranes examined (14.4%). Of those 24, 13 (54.2%) were juveniles, eight (33.3%) were subadults, and three (12.5%) were adults. Pneumoconiosis was determined in 19 (11.4%) Eurasian Cranes; three of the 19 (15.8%) were juveniles, nine (47.4%) were subadults, and seven (36.8%) were adult birds. The condition was characterized by small, brownish, birefringent particles within the cytoplasm of macrophages accumulated around peribronchial areas. Focal dystrophic calcification of the renal tubular epithelium in 3 of the 167

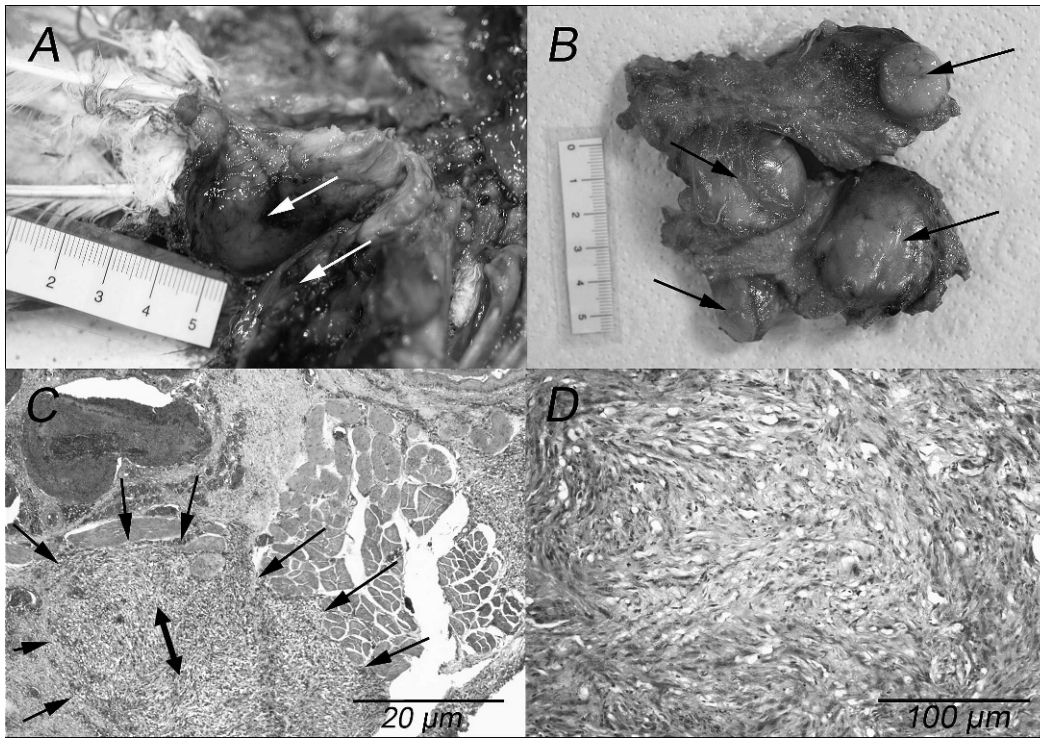

FIGURE 1. Leiomyosarcoma in an adult Eurasian Crane (*Grus grus*). A. Photograph of a cut through leiomyosarcoma within the subcutis of the left elbow, showing pale, caseous, nodular masses (arrows). B. Four well-demarcated pulmonary tumor metastases (arrows). C. Left wing, nodule of neoplastic cells (arrows) invading the subcutaneous connective tissue, H&E stain. 100×. D. Lung metastasis with multiple, spindle-shaped, and elongated tumor cells, H&E stain. 400×.

Eurasian Cranes (1.8%) was associated with focal degeneration in one Eurasian Crane and mild infiltration by lymphocytes and plasma cells in another.

Multiple tophi were observed within the kidney of one subadult and one adult Eurasian Crane and within the subcapsular area of the liver of one juvenile bird.

DISCUSSION

We compiled information about the causes of death and pathologic changes in Eurasian Cranes from Germany. Postmortem studies are recommended by the International Union for the Conservation of Nature and Natural Resources (Meine and Archibald, 1996) to provide fundamental information for use in comparative studies of the species in other regions of its distribution and in studies of more-endangered Crane species. The causes of mortality detected in Eurasian Crane carcasses collected opportunistically may be indicative of threats on a population level. However, carcass retrieval can be limited in free-ranging Eurasian Crane populations with wide dispersal and migratory ranges, depending on accessibility of the sites (terrain structures), season (elevated temperature increasing rates of decomposition), and occurrence of predators. Cranes included in this study were opportunistically collected from an observer network through a standing active call for Eurasian Crane cases. Diseased Eurasian Cranes that died in remote or undisturbed areas were less likely to be found by humans compared with those that died through contact with anthropo-

genic structures. Therefore, we expected traumatic death to be more frequently found in our study than was disease-associated mortality.

The most frequent cause of death was collision with power lines. Morkill and Anderson (1991) indicated that large-bodied and broad-winged birds, like Eurasian Cranes, are less maneuverable and at higher risk for collisions when attempting to fly over these structures. We found that flight collisions occurred more frequently during the first and second quarter of the year. The collision risk greatly depended on the terrain, weather conditions, and bird behavior within gathering grounds (Sundar, 2005). A higher collision risk was predicted for areas with power lines connecting Eurasian Crane feeding sites and roosts (Brown and Drewien, 1995; Langgemach, 1997). Mortality caused by collisions with power lines observed in Eurasian Cranes and Sandhill Cranes (*Grus canadensis*) was more often observed during sudden changes of weather conditions (e.g., fog; Tacha et al., 1979; Prange, 1989).

Electrocution was primarily seen at medium-voltage lines that combine the risk of deadly voltage (1–60 kV) and relatively small insolation tracks between line segments (Langgemach, 1997). The 10 electrocuted Eurasian Cranes in our study (6%) had typical burn marks on feathers and skin. However, blunt-force trauma from power line collisions, including multiple fractures, organ ruptures, and internal bleeding, were seen in some of the Eurasian Cranes. To reduce the risk of collision, markings that are easily seen by birds have been suggested, in particular for high-risk locations where collisions have occurred or may occur. In high-density population areas, the benefit of modifications to existing power lines, using visibility-enhancement devices (e.g., marker balls and bird diverters), has been effective (Brown and Drewien, 1995).

Collisions with wind turbines were not detected in this study. In general, Crane flight collisions with wind turbines have been uncommon but may have resulted from limited visibility under foggy conditions. At locations where wind turbines and power lines are located near important flyways and stopover sites used frequently by Cranes, the collision risk may be higher (Ihde and Vauk-Hentzelt, 1999).

Cranes killed by car or airplane strikes are rarely mentioned in the literature. In our study, four vehicular collisions (2.4%) and one flight collision with a light aircraft (0.6%) caused direct mortality due to severe trauma and crush injuries. Forrester and Spalding (2003) and Sundar (2005) observed vehicular collisions with Sandhill Cranes and Sarus Cranes (*Grus antigone*), respectively, at feeding sites that were near to roads and areas of higher abundance of these birds. Results of their studies indicated that all birds were vulnerable to vehicular traffic because roads were not perceived as barriers.

Special wire fences are used to keep wildlife out of new plantations within forests in Germany. This type of fence consists of a larger mesh size at the top and smaller mesh size at the ground. Some Cranes were entangled with their legs or wings in the meshes, where they were caught until they died. Our finding of only three Eurasian Cranes with lead shot pellets is in accordance with earlier evidence that Eurasian Cranes being killed by gunshot is rare in most parts of Europe (Prange, 1989).

Traumatic injury determined to be predation included observed attacks by White-tailed Sea Eagles on two juvenile and one adult Eurasian Crane. One juvenile Eurasian Crane was killed by a red fox (*Vulpes vulpes*). Juvenile Eurasian Cranes have been observed being preyed upon by raccoons (*Procyon lotor*) and avian species such as Marsh Harriers (*Circus aeruginosus*) and Common Ravens (*Corvus corax*; Mewes, 1995). Based on observed Eagle attacks, detected injuries, which included laceration and punc-

ture wounds of the skin and muscles, as well as muscular hemorrhages around the sternum and neck, were attributed to the predator.

Zinc phosphide intoxication was previously documented in a single incidence when a mass-mortality event of more than 50 Cranes and hundreds of Geese (*Anser* spp.) occurred in Germany in 2004 (Prange, 2005). We examined 28 of these Eurasian Cranes shortly after death to verify the intoxication. According to toxicity data and classifications (Smith, 1987), that rodenticide is highly toxic to Eurasian Cranes. Following ingestion, intoxication occurs when zinc phosphide reacts with water and hydrochloric acid in the gastrointestinal tract. Within a few hours, the phosphine gas inhibits enzyme systems and leads to central respiratory paralysis and asphyxia (Chitty and Southern, 1954). Because of widespread application and occasional mishandling of pesticides in agriculture, Crane intoxications have occurred rather frequently (Ilyashenko, 2002). In 2008, new cases were reported by nature conservation authorities in Germany shortly after a widespread application of the rodenticide chlorphacinon (Ratron®, frunol delicia GmbH, Delitzsch, Germany), which was known to induce mortality in other wildlife species as well.

Three Eurasian Cranes had granulomatous lesions consistent with *Mycobacterium* sp. infection. Avian tuberculosis has occurred in particular within large congregations of birds (Scope, 2003). Information about the prevalence of the disease in free-ranging Eurasian Cranes is limited. When resting grounds are contaminated, the infection may become widespread as mycobacteria are resistant to environmental conditions (Thoen et al., 1977). *Aspergillus* spp. was the most common fungal infection in the Eurasian Cranes we examined. Higher proportions of fungal infections have been reported from Eurasian Cranes in captivity where the load of fungal spores was presumed to be higher from contaminated food or wood shavings (Carpenter, 1993).

Poxvirus infection has been reported in almost 60 bird species worldwide, including Sandhill Cranes (Simpson et al., 1975). Field observations of poxvirus lesions in free-ranging Eurasian Cranes, including six infected individuals in this study, suggest a higher prevalence of poxvirus infection than previously reported. Although the infection was deemed incidental, the adenovirus-like particles we observed in the kidneys of a female Eurasian Crane represent the first case, to our knowledge, suggestive of adenovirus infection in Eurasian Cranes.

There are very few reports of neoplasia in free-ranging and captive Eurasian Cranes. The leiomyosarcoma we detected in one adult individual is considered the first documented case in free-ranging Eurasian Cranes. Spalding and Woodard (2003) reported chondrosarcomas in Sandhill Cranes and Whooping Cranes (*Grus americana*).

Disease susceptibility is frequently increased with a high parasite load (Carpenter, 1993), and the prevalence of infectious diseases is likely to increase when Eurasian Cranes congregate in small areas. We identified parasitic infection more frequently than bacterial or viral infection, but in only one case was that infection associated with overt disease, which was in an adult Eurasian Crane with a severe infection of tapeworms that led to intestinal obstruction, cachexia, and death. The prevalence of cachexic Eurasian Cranes (1.8%) was low, with one case of malformation of the beak. In two other cases, the underlying cause for the emaciation was not clear.

Parasites occurred in the trachea and air sacs, as well as in the upper and lower gastrointestinal tract, and were primarily nematodes or trematodes, which have been commonly reported in other Crane species (Spalding et al., 1996). One parasite, the trematode *Prosthogonimus cuneatus*, was found in the bursa of

Fabricius of juvenile Eurasian Cranes. These flukes are transmitted indirectly via aquatic invertebrates, fish, and amphibians when Cranes forage in aquatic environments. Our finding of the trematode *Strigea* sp., in eight Eurasian Cranes (4.8%), is considered the first description, to our knowledge, of this parasite in Eurasian Cranes. Dubois and Rausch (1964) described one species, *Strigea gruis*, in Sandhill Cranes.

Although the roundworm *P. ardeae* occurred in high prevalence (Table 3), only three Eurasian Cranes (1.8%) died from severe infection with that nematode. *Hovorkonema variegatum* infesting the air sacs was detected at a low prevalence, as reported previously (Krone et al., 2007).

Abundance of Eimerian oocysts in the soil at breeding and wintering grounds increased substantially with large concentrations of Eurasian Cranes and may have facilitated coccidiosis in free-ranging Eurasian Crane populations. Thus, especially for juvenile Cranes that are more susceptible to parasites and diseases, DVC is regarded as a major threat to free-ranging juvenile Sandhill Cranes and Whooping Cranes in North America (Carpenter, 1993). Although DVC was a frequent disease of Crane chicks in captivity (Kwon et al., 2006), the finding of extraintestinal coccidian parasites in two free-ranging juvenile Eurasian Cranes was considered incidental.

Lowenstine and Munson (1999) determined that iron deposition was secondary to chronic inflammation but also due to hemorrhage, hematoma, and ulcer. In our study, iron deposition was most frequently noted in Eurasian Cranes poisoned by zinc phosphide.

In summary, the main causes of mortality in the examined Eurasian Cranes were anthropogenic and included impact with power lines, unintentional poisoning with rodenticides, electrocution, and entanglement in wires and fences. Although direct transmission of parasites and other infectious disease agents are more likely to increase with high congregations of birds at feeding sites, those diseases seemed to play a subordinate role as mortality factors. However, the number of examined cases of natural mortality was limited because of scavenging of the dead birds. Newly recognized parasites and diseases in Eurasian Cranes are the trematode *Strigea* spp. and leiomyosarcoma.

ACKNOWLEDGMENTS

The authors are grateful for financial support from the German Federal Environmental Foundation (DBU) and the Nature Conservation Fonds Brandenburg. One of us, J.F., received a PhD grant from the DBU. We thank Kirsi Blank, Marion Biering, Doris Krumnow, and Dagmar Viertel for technical support at the IZW, and Stefanie Speck and Nadine Jahn for assistance in bacteriologic research. We especially thank the Crane Conservation Group in Germany; the Bird Protection Centre in Buckow, Germany; the Nature Conservation Centre in Woblitz, Germany; the Clinic for Small Animals at the Free University in Berlin, Germany; the State Office for Agriculture, Food Safety and Fishery in Rostock, Germany; and the Biosphere Reserve Niedersaechsische Elbtalaue, Germany; and the Vonderau Museum in Fulda, Germany. In addition, we would like to thank two anonymous reviewers and the assistant editor who made valuable suggestions to improve the quality of the manuscript.

LITERATURE CITED

Brown, W. M., and R. C. Drewien. 1995. Evaluation of two power line markers to reduce crane and waterfowl collision mortality. Wildlife Society Bulletin 23: 217–227.

Carpenter, J. W. 1993. Infectious and parasitic diseases of cranes. *In* Zoo and wild animal medicine: Current therapy 3, M. E. Fowler (ed.). W. B. Saunders Company, Philadelphia, Pennsylvania, pp. 229–237.

Chitty, D., and H. N. Southern. 1954. Properties of the poison used in rodent control. *In* Control of rats and mice, Vol. 1, D. Chitty (ed.). Clarendon Press, New York, New York, pp. 102, 106–108.

Dubois, G., and R. L. Rausch. 1964. Studies on the helminth fauna of Alaska, XL: *Strigea gruis* sp. n., a trematode parasite of *Grus canadensis* (L.). Journal of Parasitology 50: 445–447.

Forrester, D. J., and M. G. Spalding. 2003. Parasites and diseases of wild birds in Florida. University Press of Florida, Gainesville, Florida, pp. 513–740.

HARTWICH, G. 1975. Rhabditida und Ascaridida. Die Tierwelt Deutschlands, 62—Teil: Rhabditida und Ascaridida. Gustav Fischer Verlag, Berlin, Germany, 256 pp. [In German.]

———. 1994. Strongylida: Strongyloidea und Ancylostomatoidea—Die Tierwelt Deutschlands, Vol. 68. Gustav Fischer Verlag, Berlin, Germany, 157 pp. [In German.]

IHDE, S., AND E. VAUK-HENTZELT. 1999. Vogelschutz und Windenergie—Konflikte, Lösungsmöglichkeiten und Visionen. Bundesverband Windenergie e.V., Osnabrueck, Deutschland, 155 pp. [In German.]

ILYASHENKO, E. 2002. Mass mortality of animals in central Mongolia. Crane Working Group of Eurasia Newsletter 4, Moscow, Russia, pp. 93–94.

KRONE, O., E. HENNE, B. BLAHY, W. MEWES, G. NOWALD, P. SOEMMER, T. LANGGEMACH, K. MUELLER, AND P. WERNICKE. 2003. Preliminary results: Causes of death and diseases of the Eurasian Crane (*Grus grus*) in Germany. *In* Proceedings of the 7th Scientific Meeting of the European Committee of the Association of Avian Veterinarians and 5th European College of Avian Medicine and Surgery, Tenerife, Spain, 22–26 April, pp. 230–236.

———, D. FRIEDRICH, AND M. HONISCH. 2007. Specific status and pathogenicity of syngamid nematodes in bird species (Ciconiiformes, Falconiformes, Gruiformes) from Germany. Journal of Helminthology 81: 67–73.

KWON, Y. K., W. J. JEON, M. L. KONG, J. H. KIM, AND G. H. OLSEN. 2006. Disseminated visceral coccidiosis in a wild white-naped crane (*Grus vipio*). Journal of Wildlife Diseases 42: 712–714.

LANGGEMACH, T. 1997. Stromschlag oder Leitungsanflug? Erfahrungen mit Großvogelopfern in Brandenburg. Zeitschrift für Vogelkunde und Naturschutz in Hessen, Vogel und Umwelt, Germany, pp. 167–176. [In German.]

LOWENSTINE, L. J., AND L. MUNSON. 1999. Avian medicine: Iron overload in the animal kingdom. *In* Zoo and wild animal medicine: Current therapy, 4th Edition, M. E. Fowler and R. E. Miller (eds.). W. B. Saunders Company, Philadelphia, Pennsylvania, pp. 260–268.

MCDONALD, M. E. 1981. Key to trematodes reported in waterfowl. US Department of the Interior, Fish and Wildlife Service Resource Publication 142, 156 pp.

———. 1988. Key to Acanthocephala reported in waterfowl. US Department of the Interior, Fish and Wildlife Service Resource Publication 173, 45 pp.

MEINE, C. D., AND G. W. ARCHIBALD. 1996. The cranes: Status survey and conservation action plan, Section 1. International Union for the Conservation of Nature and Natural Resources/Species Survival Commission of the Crane Specialist Group, Gland, Switzerland and Cambridge, UK, pp. 18–25, 159–172.

MEWES, W. 1995. Bestandsentwicklung des Kranichs *Grus grus* in Deutschland und deren Ursachen. PhD Dissertation. Mathematisch-Naturwissenschaftlich-Technische Fakultät der Martin-Luther-Universität, Halle-Wittenberg, Germany, 111 pp. [In German.]

———, G. NOWALD, AND H. PRANGE. 2003. Der Kranich—Mythen, Forschung, Fakten, 2nd Edition. G. Braun Buchverlag, Karlsruhe, Deutschland, 107 pp. [In German.]

MORKILL, A. E., AND S. H. ANDERSON. 1991. Effectiveness of marking power lines to reduce Sandhill crane collisions. Wildlife Society Bulletin 19: 442–449.

MOZGOVOI, A. A. 1968. Ascaridata of animals and man and the diseases caused by them. *In* Essentials of nematodology, Vol. 2, K. I. Skrjabin (ed.). Academy of Sciences of the USSR, Moscow, Russia, 367 pp.

PRANGE, H. 1989. Der Graue Kranich. Neue Brehm Buecherei. A. Ziemsen Verlag, Wittenberg/Lutherstadt, Deutschland, 272 pp. [In German.]

———. 2005. Crane migration, resting and protection 2004. AG Kranichschutz Deutschland, European Crane Working Group, Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany, 87 pp. [In German.]

———. 2007. Crane migration, resting and wintering 2006/ 2007. AG Kranichschutz Deutschland, European Crane Working Group, Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany, 96 pp. [In German.]

SCOPE, A. 2003. Bakterielle Erkrankungen. *In* Kompendium der Ziervogelkrankheiten, 2nd Edition, E. J. Kaleta and M.-E. Krautwald Junghanns (eds.). Schluetersche GmbH & Co. KG, Hannover, Germany, pp. 229–249. [In German.]

SIMPSON, C. F., D. J. FORRESTER, AND S. A. NESBITT. 1975. Avian pox in Florida sandhill cranes. Journal of Wildlife Diseases 11: 112–115.

SMITH, G. J. 1987. Pesticide use and toxicology in relation to wildlife: Organophosphorus and carbamate compounds. US Fish and Wildlife Service Resource Publication 170, Washington D.C., 171 pp.

SPALDING, M. G., J. M. KINSELLA, S. A. NESBITT, M. J. FOLK, AND G. W. FOSTER. 1996. Helminth and arthropod parasites of experimentally introduced whooping cranes in Florida. Journal of Wildlife Diseases 32: 44–50.

———, AND J. C. WOODARD. 2003. Cranes. *In* Parasites and diseases of wild birds in Florida, D. J. Forrester and M. G. Spalding (eds.). University Press of Florida, Gainesville, Florida, pp. 704–740.

SPASSKY, A. A., K. I. SKRJABIN, L. F. BOGARENKO, AND L. P. SPASSKAYA. 1971. *Gruitaenia lattissima* g. n.,

sp. n.: A new species of a new genus of dilepidid cestodes in cranes. Izvestiya Akademii Nauk Moldavskoy SSR. Nauk 5: 61–65.

SUNDAR, K. S. G. 2005. Mortality of herpetofauna, birds and mammals due to vehicular traffic in Etawah District, Uttar Pradesh, India. Journal of the Bombay Natural History Society 101: 392–398.

TACHA, T. C., D. C. MARTIN, AND C. G. ENDICOTT. 1979. Mortality of sandhill cranes associated with utility high lines in Texas. *In* Proceedings of the 1978 North American Crane Workshop, J. C. Lewis (ed.). Rockport, Texas, 6–8 December; Colorado State University and National Audubon Society, Fort Collins, Colorado, pp. 175–176.

THOEN, C. O., E. M. HIMES, AND R. E. BARRETT. 1977. Mycobacterium avium serotype 1 infection in a sandhill crane (*Grus canadensis*). Journal of Wildlife Diseases 13: 40–42.

YAMAGUTI, S. 1959. Systema helminthum, Vol. 2: The cestodes of vertebrates. Interscience Publishers, New York, New York, 860 pp.

———. 1971. Synopsis of digenetic trematodes of vertebrates, Vol. I. Keigaku Publishing Company, Tokyo, Japan, 1074 pp.

ZOELLNICK, H. H. 1984. Beobachtungen an Stand- und Nahrungsplätzen des Kranichs (*Grus grus*) im Herbst 1982. Ornithologischer Rundbrief Mecklenburg N. F. 27: 3–8. 1[In German.]

Submitted for publication 18 April 2010.
Accepted 16 March 2011.