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SUMMARY OF MORTALITY AMONG CAPTIVE CRANES AT THE INTERNATIONAL CRANE FOUNDATION: 2000-2020

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***Abstract*:** We reviewed mortalities of captive cranes at the International Crane Foundation (ICF) between 2000 and 2020 to provide broad insights into contemporary factors affecting the collection's health and survival. Sixty-three deaths were documented in 13 of 15 crane species held in the ICF collection. The mean annual mortality during the study was 2.6% and the mean age (±SD) at death was 28.4 (±12.7) years. The overall total number of deaths of males and females was similar, but there was an association between sex and death of adult versus geriatric (>25 years) cranes ($P < 0.01$); males were more likely to die at geriatric age than females. Deaths were commonly associated with chronic health and management problems ($n = 44$, 79%) versus problems with an acute onset ($n = 12$, 21%). Common causes of death in captive cranes were due to musculoskeletal problems (44%), trauma (9%), and neoplastic disease (8%). Infectious pathogens were associated with respiratory (6%), reproductive (4%), and gastrointestinal (2%) deaths. Our findings add to previous reviews of mortality among captive cranes by detailing problems associated with progressive aging of individuals in the ICF collection.

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Key words: captivity, cause of death, cranes, Gruidae, mortality.

Tracking the incidence of mortality in captive animal collections helps inform management programs aimed at improving population health, production, and sustainability. For example, previously published summaries of whooping crane (*Grus americana*) mortalities are assisting captive breeding centers of the recently formed Whooping Crane Species Survival Plan program (Carpenter and Derrickson 1982, Olsen et al. 1997*a*, Hartup et al. 2010). The large collection of the International Crane Foundation (ICF) offers a unique opportunity to compare mortality factors across a wide variety of species and broaden our understanding of longevity, health, and disease across members of the Gruidae. This study summarized primary health and management problems associated with the deaths of subadult and adult captive cranes and identified areas for further emphasis and management.

The medical records of all accessioned cranes that died at ICF during 2000-2020 were reviewed ($n = 124$). This time period was chosen because it represents an era of consistent husbandry, captive breeding, and veterinary care focused on meeting sustainability goals for exotic species with Association of Zoos and Aquariums managed population plans, as well as genetic, demographic, and production goals of domestic whooping crane recovery activities at ICF. Sixty-one deaths of juveniles less than 1 year of age were excluded from further analysis since they were heavily weighted to whooping cranes and described elsewhere (Hartup et al. 2010, Keller and Hartup 2013). The study population consisted of 63 individuals that died during this time period, including 5 subadults (1 to <4 yr; 1 M, 4 F), 17 adults (4 to <25 yr; 4 M, 13 F), and 41 geriatric (≥25 yr; 25 M, 16 F) cranes. These age classifications are generalizations across the taxon, but consistent with those used by Hartup et al. (2010) for whooping cranes.

The primary health and management problems causally associated with each mortality were ascribed to 1 of 14 categories based on curatorial and necropsy records: cardiac, gastrointestinal, iatrogenic, infectious disease, management decision, musculoskeletal, neoplasia, neurologic, renal, reproductive, respiratory, trauma, welfare concern, and unknown. Additional descriptors, such as species, whether death was natural or by humane euthanasia, associated with an acute or long-standing, chronic problem, anatomic location, or specific disease diagnoses were also recorded. A measure of annual mortality rate was calculated by dividing the number of deaths in a calendar year by the total number of cranes >1-year-old in the ICF collection accessioned during that year.

Deaths involved individuals of 13 species; no black crowned crane (*Balearica pavonina*) or demoiselle crane (*Anthropoides virgo*) died at ICF during the study period while the collection minimally included 2 individuals of each species annually. Six species accounted for the majority of deaths: red crowned crane (*G. japonensis*,

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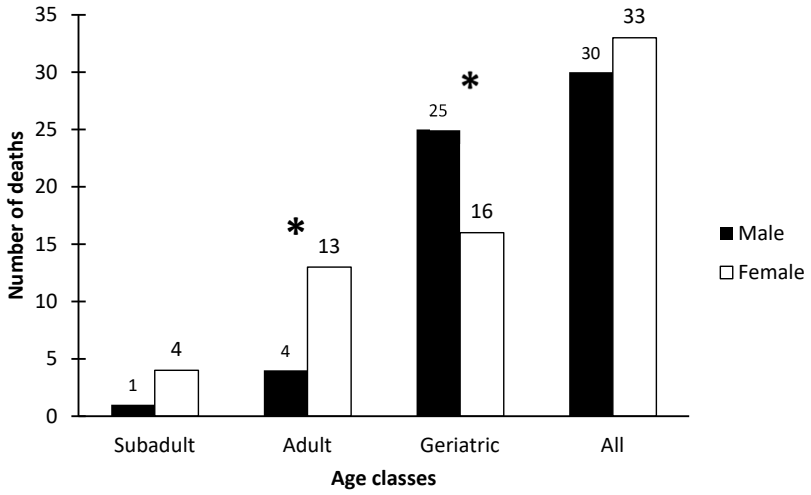

Figure 1. The number of deaths of cranes by sex among post-juvenile age classes at the International Crane Foundation, Baraboo, Wisconsin, 2000-2020. Asterisk (*) denotes a statistical difference ($P < 0.01$) in the proportion of males and females that died in adult and geriatric age classes.

n = 6), sandhill crane (*G. canadensis*, *n* = 9), Siberian crane (*Leucogeranus leucogeranus*, *n* = 8), white-naped crane (*G. vipio*, *n* = 6), and whooping crane (*n* = 15). Total mortalities of the species approximated the proportion of each within the entire captive collection over the study period. The mean annual mortality rate within the ICF captive collection during the study period was 2.6% (range 0.0-6.1%, median = 2.7%). Mean ± SD annual total crane flock size was 112 ± 5 cranes (range 106-124, median = 111).

The mean age ± SD of cranes at death was 28.4 ± 12.7 years (range 1-55 yrs, median = 31.6 yrs). The overall total number of deaths of males differed little from females, but there was an association between sex and death of adult versus geriatric cranes ($\chi^2 = 6.74$, $P < 0.01$, Fig. 1). Fourteen cranes were found dead (22%) and 49 (78%) were humanely euthanized per the ICF euthanasia policy based on poor medical prognosis, declining welfare concerns, and/or limited value to broader crane conservation. A large majority of deaths were associated with a chronic health or management problem (*n* = 44, 79%) versus an acute one (*n* = 12, 21%). The occurrence of both chronic problems and euthanasia was greatest among geriatric cranes.

The most common causes of death in the captive cranes were due to musculoskeletal problems (44%), trauma (9%), and neoplastic disease (cancers; 8%) (Table 1). Infectious diseases often involved primary or secondary pathogens associated with respiratory (6%), reproductive (4%), and gastrointestinal (2%) mortalities. The cause of death remained unknown in 7 (11%) deaths despite detailed postmortem analyses. Management decisions led to humane euthanasia of 6 cranes (9%) that were surplus to ICF collection plans and unable to be relocated.

The findings of this review add to previous reviews of health problems among captive cranes (MacLean and Beaufrere 2015, Olsen et al. 2019) by detailing problems associated with progressive aging of cranes in the ICF collection. The captive husbandry and veterinary programs at ICF have been very successful at lowering preventable deaths (due to parasitism, iatrogenic traumas, foodborne illness, secondary infections of minor conditions), often through early detection, and prolonging lifespans. Thus, the majority of deaths at ICF have recently occurred in cranes of advanced age, involved chronic health problems, and often necessitated humane euthanasia to relieve growing welfare concerns over debility and lowered quality of life. The ages of the cranes also highlight a growing concern about sustainability of some captive crane management programs since normal population age structure is typically based on greater numbers of younger individuals: that structure is now inverted due to limited opportunities for captive breeding, dispersal/importation, space requirements, staffing, expertise, and demand for exhibition among the network of partner institutions (Wilson et al. 2019). Veterinary and curatorial programs increasingly will need to modify or develop preventive diagnostic techniques and routines,

Table 1. Primary causes of mortality among age classes of captive cranes at the International Crane Foundation, Baraboo, Wisconsin, 2000-2020.

Primary problem	Subadult	Adult	Geriatric	All
Cardiac	0	0	0	0
Gastrointestinal	0	0	1	1
Iatrogenic	0	0	0	0
Management decision	0	2	4	6
Musculoskeletal	2	8	18	28
Neoplasia	0	1	4	5
Neurologic	0	0	1	1
Renal	0	0	0	0
Reproductive	0	1	3	3
Respiratory	2	1	1	4
Trauma	0	3	3	6
Welfare concern	0	0	1	1
Unknown	1	1	5	7
Total events	5	17	41	63

therapeutics, and management solutions to meet needs in older individuals and support their remnant productivity, good quality of life, and conservation value.

Musculoskeletal problems, such as osteoarthritis and severe traumatic injury to extremities are the greatest risk to long-term health of captive cranes (Hartup et al. 2018) and were confirmed in our results. Frequent diagnostic workups are warranted to track progression of degenerative joint disease, as well as further study of currently available and newer analgesics in avian medicine, and complementary therapeutic regimens such as physical therapy and photobiomodulation treatment (Pryor and Millis 2015). The application of best practices must be maintained to minimize non-life-threatening injuries during capture and restraint, some of which lead to osteoarthritis in later life, as well as accidental iatrogenic (human-caused) deaths.

This study documented a higher-than-expected incidence of neoplastic disease coinciding with several aged individuals. A large retrospective review estimated a similar proportion (7.4%) of cranes necropsied across North American zoos had tumors at the time of death (Hawkins et al. 2021). The most common tumor types involved the gastrointestinal system and were biologically aggressive carcinomas. These findings point to a need to explore diagnostic testing regimens for earlier detection (screening CT scans) and possibly even application of therapeutic options that are infrequently used in other than companion birds (e.g., chemotherapy).

Health problems complicated by the presence of bacterial and viral infections, though relatively low in incidence in this study, still demand aggressive management and prevention among captive cranes. During the 20-year period of this study, 2 significant emergent viral diseases in North America have threatened the ICF captive cranes: highly pathogenic avian influenza and West Nile virus (WNV; Hansen et al. 2008). The ICF crane care staff created new and detailed biosecurity plans (including for dedicated footwear, disinfecting footbaths, controlled entry, etc.) to prevent introduction of infectious disease into the captive flock, but they require regular reassessment and updating. In addition, endemic diseases are changing in frequency and range in Wisconsin and other regions, such as mosquito-borne Eastern Equine Encephalitis (EEE). Fortunately for both EEE and WNV, effective vaccines are used in captive cranes and losses have been very limited over the past 20 years (Olsen et al. 1997*b*, Olsen et al. 2009).

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