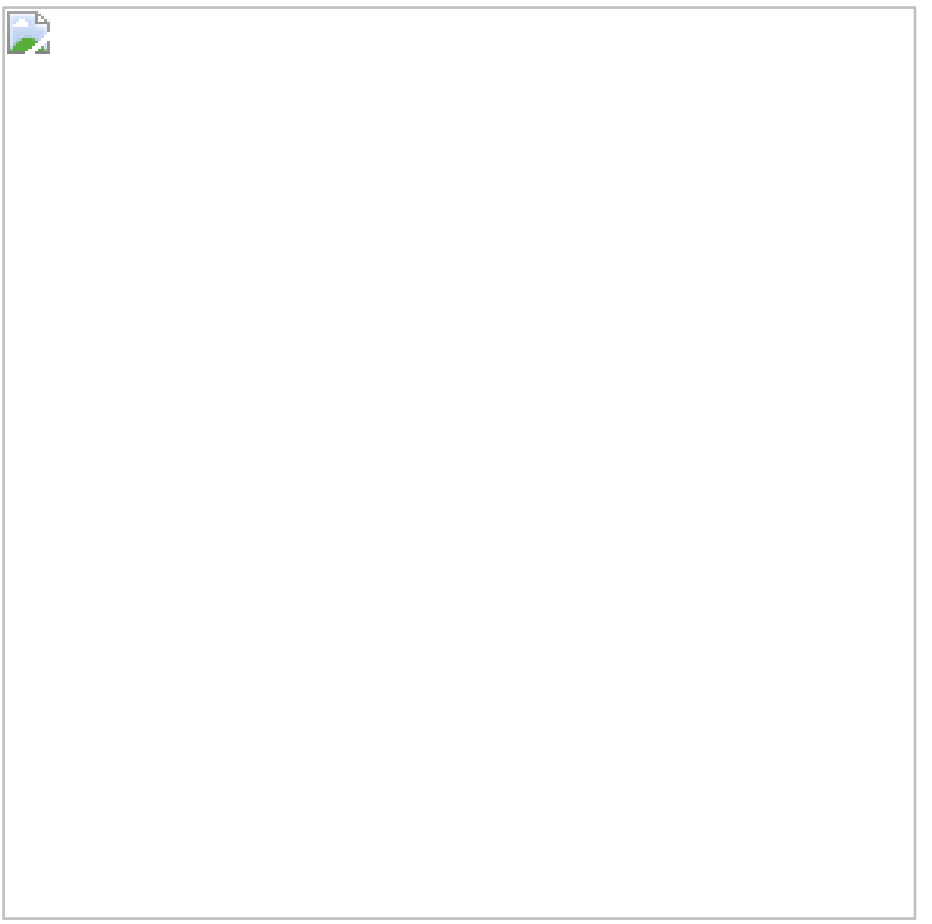

Adult Whooping Crane (Grus americana) Consumption of Juvenile Channel Catfish (Ictalurus punctatus) during the Avian Spring Migration in the Central Platte River Valley, Nebraska, USA

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Adult Whooping Crane (*Grus americana*) consumption of juvenile channel catfish (*Ictalurus punctatus*) during the avian spring migration in the Central Platte River Valley, Nebraska, USA

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Abstract.—Stopover sites provide important forage resources and protection from predators to the Aransas-Wood Buffalo population of Whooping Cranes (*Grus americana*) as they migrate 4000 km across the Great Plains each spring and fall. Given the Whooping Crane's expansive migration corridor, sensitivity to human disturbance, small population size, and protected status under the Endangered Species Act, it is challenging to gather detailed information regarding the particular forage resources that the cranes exploit at various stopover locations. On 22 March 2018 we observed and photo-documented an adult Whooping Crane consuming at least 5 individual juvenile channel catfish (*Ictalurus punctatus*) after it landed 100 m in front of our Sandhill Crane viewing blind on the south channel of the Platte River. Using the average exposed culmen length of an adult Whooping Crane for reference, we estimated that the length of the channel catfish ranged from 97 mm to 117 mm. Growth estimates developed from the Lower Platte River suggest that the depredated channel catfish were just over one year old. To the best of our knowledge, our observations represent the first definitive record of a Whooping Crane consuming fish in the Platte River, as well as the first record of a Whooping Crane depredating a channel catfish in the Great Plains. Given the relatively long distances at which Whooping Cranes are generally viewed (≥650 m), small-bodied fish may be a more common prey item during migration than indicated by current scientific literature. Our note demonstrates how wildlife photography and ecotourism can contribute to our understanding of species' natural histories.

Resumen.—Las zonas de descanso ofrecen importantes recursos para forrajeo y protección contra depredadores a la población de Grullas Trompeteras (*Grus americana*), ya que estas migran 4000 km a través de las Grandes Llanuras cada primavera y otoño. Debido a la extensión de su ruta migratoria, la sensibilidad a la perturbación humana, la población reducida y el estado de protección bajo la Ley de Especies en Peligro de Extinción en la que se encuentra esta especie, resulta complejo la recopilación de información detallada acerca de los recursos que las grullas trompeteras explotan para forrajear, en las diferentes zonas de descanso. El 22 de marzo del 2018 detectamos y documentamos fotográficamente una grulla trompetera adulta consumiendo por lo menos 5 ejemplares juveniles de peces gato (*Ictalurus punctatus*), después de aterrizó a 100 m de nuestra ventana con vistas a las Grullas Canadienses del canal Sur del río Platte. Tomando como referencia la longitud promedio del culmen de una grulla canadiense, estimamos que la longitud del pez gato varió de 97 mm a 117 mm. Las estimaciones de crecimiento obtenidas del río Lower Platte sugieren que el pez gato depredado tenía más de un año de edad. Hasta donde conocemos, nuestras observaciones representan el primer registro definitivo de una grulla canadiense en el río Platte, así como el primer registro de una grulla canadiense depredando a un pez gato en las Grandes Llanuras. Debido a que generalmente las Grullas Canadienses son detectadas a distancias relativamente largas (≥650 m), los peces de cuerpo pequeño pueden ser un objeto de presa más común durante los períodos migratorios de lo que indica la literatura científica actual. Nuestro artículo demuestra cómo la fotografía de vida silvestre y el ecoturismo pueden contribuir a comprensión de la historia natural de las especies.

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Whooping Cranes (*Grus americana*) undertake a biennial north–south migration of approximately 4000 km through the Great Plains of North America (Kuyt 1992, Pearse et al. 2018). Their migration corridor averages about 300 km in width and traverses the Central Platte River Valley (CPRV), Nebraska (Pearse et al. 2018). The U.S. Fish and Wildlife Service designated the Platte River Bottoms between Lexington and Denman, Nebraska, as one of the 5 critical habitats in the Central Flyway for the Aransas-Wood Buffalo Population of Whooping Cranes (USFWS 1978). The Platte River is a braided prairie river characterized by shifting exposed and submerged sandbars that provide night roosting and foraging habitat for both Sandhill Cranes (*Antigone canadensis*) and Whooping Cranes (Smith 1971, Currier and Ziewitz 1987, Farmer et al. 2005, Kinzel et al. 2009). Historically, the main channel of the Platte River was bordered by prairie habitats and exceeded 1.6 km in width in many locations, but it has become narrower and more wooded with the appropriation of river flows for human use (Williams 1978, Currier 1982, Johnson 1994).

Today the CPRV landscape is a mosaic of irrigated agricultural fields, riparian woodlands, lowland tallgrass prairies, wet meadows, and linear wetlands called "sloughs" (Currier 1982, 1989, Kaul et al. 2006, Brei and Bishop 2008, Whiles et al. 2010, Krapu et al. 2014, Caven et al. 2017). The diversity of wetlands and agricultural fields in the CPRV provides quality stopover habitat for Whooping Cranes (Lingle et al. 1991, Chávez-Ramírez and Weir 2010, Jorgensen and Dinan 2016, Pearse et al. 2017). Stopover sites are necessary for migrating birds as they provide forage resources and protection from predators (Alerstam and Högstedt 1982, Newton 2006). Whooping Cranes prefer wide, unobstructed view widths away from forests, channel widths over 150 m, vegetation under 1.5 m in height, and a lack of human disturbances (Lingle et al. 1991, Faanes 1992, Faanes et al. 1992, Farmer et al. 2005, Howlin and Nasman 2017, Pearse et al. 2017). One of the major risks facing Whooping Cranes is the loss of wetland habitats to development (Meine and Archibald 1996). Stahlecker (1992) found that there were 4 or fewer suitable wetland roosting locations per 100 km^2 of the migration corridor through Oklahoma. By contrast, Nebraska contains suitable stopover habitat throughout the migration corridor (Stahlecker 1997).

Forage patterns have been more thoroughly researched on wintering and breeding grounds than they have been during migration. Whooping Crane diet on the wintering grounds in coastal Texas is well studied, revealing that the species primarily subsists on blue crabs (*Callinectes sapidus*), common fiddler crabs (*Uca pugilator*), razor clams (*Tagelus plebeius*), snails (*Littorina* spp., *Melampus coffeus*, and *Cerithidea pliculosa*), crayfish (*Cambarus* spp.), acorns (*Quercus* spp.), and wolfberry (*Lycium carolinianum*) fruits, while occasionally consuming vertebrates such as snakes (*Nerodia clarkii clarkii*) (Allen 1952, 1954, Uhler and Locke 1970, Blankinship 1976, Hunt and Slack 1989, Chávez-Ramírez 1996, Westwood and Chávez-Ramírez 2005, Greer 2010, Geluso and Harner 2013). Data from the breeding grounds at Wood Buffalo National Park in Canada suggests that they forage on fish (*Culaea inconstans*, *Pimephales promelas*, and Cyprinidae), snails (*Lymnaea stagnalis* and *Helisoma* spp.), dragonflies (*Libellula* spp. and *Aeshna* spp.), and diving beetles (*Rhantus binotatus*, *Acilius semisulcatus*, *Graphoderus occidentalis*, and *Dytiscus alaskanus*) (Novakowski 1966, Bergeson et al. 2001, Sotiropoulos 2002, Classen 2008). Incidental accounts from reintroduced populations have discovered Whooping Cranes consuming amphibians (*Ranidae*) and reptiles, including turtles (*Chelydra serpentina*, *Kinosternon subrubrum*) (Zimorski et al. 2013, Dinets 2016). However, much less is known regarding the prey items selected by Whooping Cranes during migration (Allen 1952, Austin and Richert 2001). During migration, Whooping Cranes have been recorded eating agricultural waste grains such as sorghum (*Sorghum vulgare*), wheat (*Triticum aestivum*), and corn (*Zea mays*); nutsedge tubers (*Cyperus* spp.); invertebrates including beetles, mollusks, and crayfish; as well as vertebrates including frogs (*Lithobates blairi*), fish, snakes, salamanders, and small mammals (Allen 1952, USFWS 1978, 1981, Kauffeld 1981, Howe 1987, Kuyt 1987, Austin and Richert 2001, 2005, Geluso et al. 2013). However, most of these data comes from incidental observations made from long physical distances; therefore, very little species-specific information exists regarding the variety of prey items consumed by Whooping Cranes during migration. In this report, we

Fig. 1. Photo of an adult Whooping Crane (*Grus americana*), with a channel catfish (*Ictalurus punctatus;* estimated at just over one year old) in its bill, moving among Sandhill Cranes (*Antigone canadensis*) on 22 March 2018 at about 10:30 on the main channel of the Platte River, Hall County, Nebraska, USA. Photo by C. Steenson.

add to the sparse information concerning Whooping Crane diet during migration by describing an observation novel to the scientific literature regarding an adult feeding on multiple juvenile channel catfish (*Ictalurus punctatus*) in the CPRV.

On 22 March 2018, we observed an adult Whooping Crane consuming juvenile channel catfish within the south channel of the Platte River (40°45′45″N, 98°30′45″W; 600 m elevation; Figs. 1, 2). The viewing blind was located on the south bank of the channel on the edge of a 37.4-ha restored prairie. Ten photographers entered the viewing blind about 1 h before sunrise (06:35) to photograph roosting Sandhill Cranes (*Antigone canadensis*). At approximately 10:15 a Whooping Crane with adult plumage landed near a group of Sandhill Cranes about 100 m in front of the viewing blind. Weekly aerial Sandhill Crane surveys estimated that there were about 58,000 Sandhill Cranes within 1600 m of the viewing blind, one of the highest densities on the river (Crane Trust unpublished data). Using the "measure tool" in ArcGIS 10.5.1 and digitized aerial imagery from 2016 (ESRI 2017, RWBJV 2017), we estimated that the river channel was about 450 m wide in this location. The Whooping Crane walked along the edge of an exposed sandbar slowly bobbing its head, a physical behavior associated with foraging thought to aid in gaze stabilization and prey detection (Cronin et al. 2005, 2007). At about 10:30 we first detected the Whooping Crane catching a small fish (Fig. 1). The Whooping Crane was detected catching and consuming at least 4 more individual fish over the next 1.75 h before it took flight and left our field of view (Fig. 2). The Whooping Crane's behaviors were photodocumented using a 600 mm Nikon lens and a 100–400 mm Canon lens with a 1.4× extender.

The Whooping Crane appeared to be foraging in between 5 cm and 25 cm of water based on the level to which the tarsus was submerged in photos (tarsus length: female mean = 27.7 cm [n = 7], male mean = 28.1 cm [n = 15]; Johnsgard 1983; Fig. 2). We estimated that the Whooping Crane spent between 70% and 75% of its time foraging, with the remainder of its time dedicated to preening and interspecific

Fig. 2. Whooping Crane (*Grus americana*), capturing a channel catfish (*Ictalurus punctatus;* estimated at just over one year old) in its bill, surrounded by onlooking Sandhill Cranes (*Antigone canadensis*) on 22 March 2018 at about 10:45 on the main channel of the Platte River, Hall County, Nebraska, USA. Photo by C. Steenson.

agonistic behavior with Sandhill Cranes (see Ellis et al. 1998 for a description of agonistic behaviors). We identified all 5 fish consumed as juvenile channel catfish from a series of 19 photos taken by 2 photographers noting the following features: the presence of a forked caudal fin, the presence of an adipose fin, a lack of scales, the body-depth-to-length ratio, and the placement of pectoral fins (Page and Burr 2011; Fig. 2). We approximated the length of the channel catfish by using the average exposed culmen length (upper bill, 13.8 cm) of adult Whooping Cranes (culmen length: female mean = 13.7 cm [n = 7], male mean = 13.9 cm [n = 15]; Johnsgard 1983). We estimated that the channel catfish ranged from 70% to 85% of the crane's exposed culmen length, resulting in estimated total body lengths ranging from 97 mm to 117 mm. Holland et al. (1992) found that 1-year-old channel catfish (at annulus formation) had an average total length of 84 mm (range 69–101 mm) and that 2-year-old channel catfish ranged from 137 to 168 mm within the Lower Platte River from 1988 to 1991. These results suggest that the channel catfish the Whooping Crane was consuming were just over 1 year old.

North American Ictaluridae, including channel catfish, are territorial and communicate through chemical signals in low-light habitats (Bryant and Atema 1987, Jamzadeh 1992). However, Brown et al. (1970) found that channel catfish ≤10 months old gathered in the bottom of pools during the day when structural cover was absent; they also gathered during all hours of the day when temperatures were below 4 °C. Ambient temperatures were as low as 8 °C and water temperatures were as low as 5.7 °C during our observations (USGS 2018, Weather Underground 2018), suggesting

that any aggregation behavior was more likely to have resulted from habitat structure or predation pressure. In the absence of shelter, it is possible that these juvenile channel catfish were aggregated in the bottom of a shallow pool within the wide and open braided river channel. Power (1984) found that the spatial distribution of armored catfish (Loricariidae) appears to be determined more by avian predator avoidance than by available food resources. Though fish are not common forage resources for Sandhill Cranes, cranes have occasionally been detected depredating fish in the Platte River (Lewis 1979, Mergler Niemeier and Niemeier 1982). Given that Sandhill Crane abundance can exceed 600,000 individuals during the spring migration staging period in mid to late March (Dubovsky 2018), it is possible that channel catfish exhibit predator avoidance aggregation behavior as a response to perceived Sandhill Crane predation risk. It is also feasible that there was simply an abundance of juvenile channel catfish in this microhabitat. As Phelps et al. (2011) notes, juvenile channel catfish in the Mississippi River preferred shallow islands and off-channel habitats with sandy substrate and slow-flowing water. Finally, it is conceivable that Whooping Cranes selected for juvenile channel catfish among the available small-bodied fishes because the catfish represented preferred forage. Research regarding Double-crested Cormorants (*Phalacrocorax auritus*) suggests that channel catfish are easily digestible and provide greater energy content than gizzard shad (*Dorosoma cepedianum*) or bluegill (*Lepomis macrochirus*) (Brugger 1993).

To the best of our knowledge, our observations represent the first scientific record of a Whooping Crane depredating a channel catfish in the Platte River and in the Central Flyway. Despite the Platte River supporting 56 species of fish (Goldowitz 1996, Chadwick et al. 1997), there have been no detailed reports of Whooping Cranes depredating fish there. However, Whooping Cranes have been reported consuming fish (unidentified) in the Rainwater Basin, just south of the CPRV (USFWS 1981). Research suggests that fish are a potentially important food source for Whooping Cranes during migration (Armbruster 1990), but only Allen (1952) discusses potential prey species including the white sucker (*Catostomus commersonii sucklii*), the creek chub (*Semotilus atromaculatus*), shiner species (*Notropis* spp.), the brassy minnow (*Hybognathus hankinsoni*), and topminnow/killifish species (*Fundulus* spp.). Stable isotope analysis of Whooping Crane feathers suggests that fish are an important prey item for the Aransas-Wood Buffalo population (Duxbury and Holroyd 1996). Bergeson et al. (2001) directly observed Whooping Cranes consuming brook sticklebacks (*Culaea inconstans*) on their breeding grounds in Wood Buffalo National Park. Brook sticklebacks are also present in the Platte River Basin (Goldowitz 1996). Research from the breeding grounds also suggests that pond habitats containing small-bodied fishes such as brook stickleback, fathead minnow (*Pimephales promelas*), and dace species (*Phoxinus* spp.) received higher Whooping Crane use than ponds dominated by invertebrate species (Bergeson 1998, Classen 2008). On their wintering grounds, Whooping Cranes have also been observed consuming fish, including topminnow/killifish, sheepshead minnow (*Cyprinodon variegatus*), flathead grey mullet (*Mugil cephalus*), and speckled worm-eel (*Myrophis punctatus*) (Allen 1952, Greer 2010).

Channel catfish are important prey items for a number of wading bird species, such as Great Blue Herons (*Ardea herodias*) and Great Egrets (*Ardea alba*) (Stickley 1995, Glahn et al. 1999, 2000, Werner et al. 2001, Dorr and Taylor 2003). According to Stickley (1995) and Glahn et al. (1999), Great Blue Herons showed a preference for smaller-sized channel catfish ranging from 110 to 160 mm. Glahn et al. (1999) and Werner et al. (2001) similarly found that Great Egrets preferred catfish ranging from 75 to 103 mm. Our observations suggest that Whooping Cranes select channel catfish sizes similar to those selected by Great Blue Herons and Great Egrets (97–117 mm). Willard (1977) found that wading bird species demonstrate similar depth preferences for hunting fish; Great Blue Herons and Great Egrets preferred hunting depths of 15 to 25 cm, while Snowy Egrets and Little Blue Herons generally foraged in shallower water of 5 to 15 cm. Our observations again demonstrated significant overlap in fish foraging depths between Whooping Cranes (5 to 25 cm) and wading birds in the family Ardeidae. Water depth data collected from Whooping Crane stopover sites suggest that on average Whooping Cranes roost and forage in 14 to 20 cm of water (Howe 1987, 1989, Pearse et al. 2017). Both Great

Blue Herons and Great Egrets were predominantly observed depredating channel catfish in the spring and fall when catfish diseases, such as enteric septicemia, were more prevalent (Stickley 1995, Glahn et al. 1999, 2000). Disease could reduce the ability of channel catfish to escape and defend themselves from depredation attempts (Glahn et al. 2000). Whooping Crane migration may overlap with periods of channel catfish disease prevalence in the CPRV, making the catfish a more easily attainable food source.

Stopover sites throughout the Central Flyway provide Whooping Cranes with necessary energy reserves and safe refuge during migration (Alerstam and Högstedt 1982, Stahlecker 1992, 1997, Meine and Archibald 1996, Austin and Richert 2001, Newton 2006, Pearse et al. 2017). This observation underscores the importance of managing the CPRV holistically to benefit a broad swath of native species, such as channel catfish, brook sticklebacks, plains leopard frogs (*Lithobates blairi*) and others that fill niches in the ecosystem's food web and provide important forage resources to endangered species such as the Least Tern (*Sternula antillarum*) and the Whooping Crane (Wilson et al. 1993, Bergeson et al. 2001, Sherfy et al. 2012, Geluso et al. 2013).

Despite the importance of gathering information on Whooping Crane forage resources during migration, systematically studying crane behavior at stopover locations presents several challenges. First, Whooping Cranes can be challenging to detect even in relatively limited ranges such as their wintering grounds (Strobel and Butler 2014). Whooping Cranes, numbering about 500 individuals (Butler and Harrel 2018), migrate through a corridor spanning over 100 million ha of the Great Plains (Pearse et al. 2018), and they avoid human disturbances (Pearse et al. 2017); they are therefore challenging to locate while in migration. Moreover, Whooping Cranes are sensitive to human disturbances, including people on foot or approaching vehicles (Lewis and Slack 2008); therefore, government wildlife management authorities require a distance of approximately 650 m for public observation and most research investigations (USFWS and NGPC 2015). Consequently, most behavioral studies have been conducted at distances that only allow for a broad interpretation of foraging behavior in particular habitats but not the visual classification of forage (Lingle et al. 1991, Jorgensen and Dinan 2016). Therefore, it is possible that small-bodied fish species and the young of larger fish species may be relatively common prey items for Whooping Cranes during migration but may also be underrepresented in scientific records due to low detection probability.

Given the challenges of studying the behavior of this cryptic endangered species during migration, incidental observations play an important role in furthering our understanding of Whooping Crane natural history, and such observations provide an opportunity for citizen scientists to make significant contributions (Geluso and Harner 2013, Geluso et al. 2013). During the early spring, thousands of people flock to the CPRV to observe the Sandhill Crane migration (Dority et al. 2017); the number of tourists watching the river is vastly greater than the sum of researchers on the ground. Publically reported Whooping Crane sightings and associated photographs provide a rich information repository, which can be used to better understand habitat-use patterns and track changes in the migration corridor over time (Austin and Richert 2001, Niemuth et al. 2018, Pearse et al. 2018). Photographs also provide information regarding Whooping Crane behavior and ecology, such as the documentation of prey items and potential predators (Geluso et al. 2013, Geluso and Harner 2013, Caven et al. 2018). Publicly sourced photographs provide a form of visual evidence that can be validated and further investigated, and photographs often provide additional details depending on factors such as resolution, quality, and distance (Pimm et al. 2015). Publicly sourced images have been a useful conservation research tool for studying various wildlife species including sea turtles (Long and Azmi 2017), whale sharks (Davies et al. 2012), and cheetahs (Weise et al. 2017), as well as for monitoring protected habitat areas (Walden-Schreiner et al. 2018). In this case, images of an adult Whooping Crane eating juvenile channel catfish provided documentation of a novel forage event and allowed us to visually examine characteristics and approximate measurements of the prey. Our research further demonstrates the value of publically sourced imagery for natural history research and provides valuable insight into the variety of diet items exploited regionally by Whooping Cranes during migration.

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Literature Cited

Alerstam, T., and G. Högstedt. 1982. Bird migration and reproduction in relation to habitats for survival and breeding. Ornis Scandinavica 13:25–37.

Allen, R.P. 1952. The Whooping Crane. Research Report No. 3 of the National Audubon Society. National Audubon Society, New York, NY.

Allen, R.P. 1954. Additional data on the food of the Whooping Crane. Auk 712:198.

Armbruster, M.J. 1990. Characterization of habitat used by Whooping Cranes during migration. U.S. Fish and Wildlife Service Biological Report 90(4):1–16.

Austin, J.E., and A.L. Richert. 2001. A comprehensive review of observational and site evaluation data of migrant Whooping Cranes in the United States, 1943–99. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND.

Austin, J.E., and A.L. Richert. 2005. Patterns of habitat use by Whooping Cranes during migration: summary from 1977–1999 site evaluation data. Proceedings of the North American Crane Workshop 9:79–104.

Bergeson, D. 1998. Whooping Crane monitoring in Wood Buffalo National Park. Research Links 6:1–7.

Bergeson, D.G., M. Bradley, and G.L. Holroyd. 2001. Food items and feeding rates for wild Whooping Crane colts in Wood Buffalo National Park. Proceedings of the North American Crane Workshop 8: 36–39.

Blankinship, D.R. 1976. Studies of Whooping Cranes on the wintering grounds. Pages 197–206 *in* J.C. Lewis, editor, Proceedings of the International Crane Workshop. Oklahoma State University Publishing and Printing, Stillwater, OK.

Brei, J., and A.A. Bishop. 2008. Platte River vegetation mapping project 2005 land cover methods summary. Great Plains GIS Partnership, Grand Island, NE.

Brown, B.E., I. Inman, and A. Jearld Jr. 1970. Schooling and shelter seeking tendencies in fingerling channel catfish. Transactions of the American Fisheries Society 99:540–545.

Brugger, K.E. 1993. Digestibility of three fish species by Double-crested Cormorants. Condor 95:25–32.

Bryant, B.P., and J. Atema. 1987. Diet manipulation affects social behavior of catfish. Journal of Chemical Ecology 13:1645–1661.

Butler, M.J., and W. Harrel. 2018. Whooping Crane survey results: winter 2017–2018. U.S. Fish and Wildlife Service, Division of Biological Services, Albuquerque, NM.

Caven, A.J., K.C. King, J.D. Wiese, and E.M. Brinley Buckley. 2017. A descriptive analysis of Regal Fritillary (*Speyeria idalia*) habitat utilizing biological monitoring data along the Big Bend of the Platte River, NE. Journal of Insect Conservation 21:183–205.

Caven, A.J., J.D. Wiese, W.R. Wallauer, and K.J. Mosher. 2018. First description of a Bald Eagle (*Haliaeetus leucocephalus*) actively depredating an adult Sandhill Crane (*Antigone canadensis*). Western North American Naturalist 78:216–220.

Chadwick, J., S. Canton, D. Conklin, and P. Winkle 1997. Fish species composition in the Central Platte River, Nebraska. Southwestern Naturalist 42:279–289.

Chávez-Ramírez, F. 1996. Food availability, foraging ecology, and energetics of Whooping Cranes wintering in Texas. Doctoral dissertation, Texas A&M University, College Station, TX.

Chávez-Ramírez, F., and E. Weir. 2010. Wet meadow literature and information review: draft report. Platte River Recovery and Implementation Program, Kearney, NE, and the Platte River Whooping Crane Maintenance Trust, Grand Island, NE.

Classen, M.C.M. 2008. Monitoring potential prey of the Whooping Crane: evaluating gear types and spatial-temporal variation in aquatic fauna. Masters thesis, University of Alberta, Edmonton, CA.

Cronin, T.W., M.R. Kinloch, and G.H. Olsen. 2005. Head-bobbing behavior in foraging Whooping Cranes favors visual fixation. Current Biology 15:R243–R244.

Cronin, T.W., M.R. Kinloch, and G.H. Olsen. 2007. Head-bobbing behavior in walking Whooping Cranes (*Grus americana*) and Sandhill Cranes (*Grus canadensis*). Journal of Ornithology 148:563–569.

Currier, P.J. 1982. The floodplain vegetation of the Platte River: phytosociology, forest development, and seedling establishment. Doctoral dissertation, Iowa State University, Ames, IA.

Currier, P.J. 1989. Plant species composition and groundwater levels in a Platte River wet meadow. Proceedings of the North American Prairie Conference 11: 19–24.

Currier, P.J., and J. Ziewitz. 1987. Application of a Sandhill Crane model to management of habitat along the Platte River. Pages 315–325 *in* Lewis, editor, Proceedings of the International Crane Workshop. Platte River Whooping Crane Habitat Maintenance Trust, Grand Island, NE.

Davies, T.K., G. Stevens, M.G. Meekan, J. Struve, and J.M. Rowcliffe. 2012. Can citizen science monitor whale-shark aggregations? Investigating bias in mark-recapture modelling using identification photographs sourced from the public. Wildlife Research 39: 696–704

Dinets, V. 2016. Predation on amphibians and reptiles by reintroduced Whooping Cranes (*Grus americana*) in Louisiana. American Midland Naturalist 175:134–137.

Dority, B.R., R. Thompson, S. Kaskie, and L. Tschauner. 2017. The economic impact of the annual crane migration on central Nebraska. College of Business and Technology, University of Nebraska at Kearney, Kearney, NE.

Dorr, B., and J.D. Taylor II. 2003. Wading bird management and research on North American Aquaculture facilities. Pages 52–61 *in* K.A. Fagerstone and G.W.

Witmer, editors, Proceedings of the 10th Wildlife Damage Management Conference.

DUBOVSKY, J.A. 2018. Status and harvests of Sandhill Cranes: Mid-Continent, Rocky Mountain, Lower Colorado River Valley and Eastern populations. Administrative Report, U.S. Fish and Wildlife Service, Lakewood, CO.

DUXBURY, J.M., AND G.L. HOLROYD. 1996. The determination of the diet of Whooping Cranes on the breeding ground: a stable isotope approach. Interim Report of the Canadian Wildlife Service, Ottawa, Ontario, Canada.

ELLIS, D.H., S.R. SWENGEL, G.W. ARCHIBALD, AND C.B. KEPLER. 1998. A sociogram for the cranes of the world. Behavioural Processes 43:125–151.

[ESRI] ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. 2017. ArcGIS Desktop: Release 10.5.1. Redlands, CA.

FAANES, C.A. 1992. Unobstructed visibility at Whooping Crane roost sites on the Platte River, Nebraska. Proceedings of the North American Crane Workshop 6: 117–120.

FAANES, C.A., G.R. LINGLE, AND D.H. JOHNSON. 1992. Characteristics of Whooping Crane roost sites in the Platte River. Proceedings of the North American Crane Workshop 6:90–94.

FARMER, A.H., B.S. CADE, J.W. TERRELL, AND J.H. HENRIKSEN. 2005. Evaluation of models and data for assessing Whooping Crane habitat in the Central Platte River, Nebraska. U.S. Geological Survey Scientific Investigations Report 2005-5123.

GELUSO, K., AND M.J. HARNER. 2013. *Nerodia clarkii clarkii* (Gulf Saltmarsh Watersnake): Predation. Herpetological Review 44:156–157.

GELUSO, K., B.T. KROHN, M.J. HARNER, AND M.J. ASSENMACHER. 2013. Whooping Cranes consume Plains Leopard Frogs at migratory stopover sites in Nebraska. Prairie Naturalist 45:91–93.

GLAHN, J.F., B.S. DORR, AND M.E. TOBIN. 2000. Captive Great Blue Heron predation on farmed channel catfish fingerlings. North American Journal of Aquaculture 62:149–156.

GLAHN, J.F., D.S. REINHOLD, AND P. SMITH. 1999. Wading bird depredations on channel catfish *Ictalurus punctatus* in northwest Mississippi. Journal of the World Aquaculture Society 30:107–114.

GOLDOWITZ, B.S. 1996. Qualitative comparison of aquatic habitats and fish species diversity, today and 50 years in the Platte and North Platte Rivers of Nebraska. Progress report and preliminary data, Platte River Whooping Crane Habitat Maintenance Trust and U.S. Fish and Wildlife Service, Grand Island, NE.

GREER, D.M. 2010. Blue crab population ecology and use by foraging Whooping Cranes on the Texas Gulf Coast. Doctoral dissertation, Texas A&M University, College Station, TX.

HOLLAND, R.S., AND E.J. PETERS. 1992. Age and growth of channel catfish (*Ictalurus punctatus*) in the Lower Platte River, Nebraska. Transactions of the Nebraska Academy of Sciences and Affiliated Societies 19: 33–42.

HOWE, M.A. 1987. Habitat use by migrating Whooping Cranes in the Aransas-Wood Buffalo corridor. Pages 303–311 *in* J.C. Lewis and J.W. Ziewitz, editors, Proceedings of the 1985 Crane Workshop. Platte River Whooping Crane Habitat Maintenance Trust and U.S. Fish and Wildlife Service, Grand Island, NE.

HOWE, M.A. 1989. Migration of radio-marked Whooping Cranes from the Aransas-Wood Buffalo population: Patterns of habitat use, behavior, and survival. Technical Report No. PB-89-224992/XAB, U.S. Fish and Wildlife Service, Washington, DC.

HOWLIN, S., AND K. NASMAN. 2017. Correlates of Whooping Crane habitat selection and trends in use in the Central Platte River, Nebraska. Platte River Recovery Implementation Program, Kearney, NE, and West EcoSystems Technology, Inc., Cheyenne, WY.

HUNT, H.E., AND R.D. SLACK. 1989. Winter diets of Whooping and Sandhill Cranes in South Texas. Journal of Wildlife Management 53:1150–1154.

JAMZADEH, M. 1992. Trauma communication in channel catfish (*Ictalurus punctatus*). Pages 389–394 *in* R.L. Doty and D. Müller-Schwarze, editors, Chemical signals in vertebrates. 6th edition. Springer, Boston, MA.

JOHNSGARD, P.A. 1983. Cranes of the World. Indiana University Press, Bloomington, IN.

JOHNSON, W.C. 1994. Woodland expansions in the Platte River, Nebraska: patterns and causes. Ecological Monographs 64:45–84.

JORGENSEN, J.G., AND L.R. DINAN. 2016. Whooping Crane (*Grus americana*) behavior, habitat use and wildlife watching visitation during migratory stopover at two wildlife management areas in Nebraska 2015–2016. Nongame Bird Program, Nebraska Game and Parks Commission, Lincoln, NE.

KAUFFELD, J.D. 1981. Management of migratory crane habitat on Alamosa and Monte Vista National Wildlife Refuges. Pages 117–121 *in* J.C. Lewis, editor, Proceedings of the 1981 Crane Workshop. National Audubon Society, Tavernier, FL.

KAUL, R.B., D. SUTHERLAND, AND S. ROLFSMEIER. 2006. The flora of Nebraska. School of Natural Resources, University of Nebraska–Lincoln, Lincoln, NE.

KINZEL, P.J., J.M. NELSON, AND A.K. HECKMAN. 2009. Response of Sandhill Crane (*Grus canadensis*) riverine roosting habitat to changes in stage and sandbar morphology. River Research and Applications 25: 135–152.

KRAPU, G.L., D.A. BRANDT, P.J. KINZEL, AND A.T. PEARSE. 2014. Spring migration ecology of the Mid Continent Sandhill Crane Population with an emphasis on use of the Central Platte River Valley, Nebraska. Wildlife Monographs 189:1–41.

KUYT, E. 1987. Whooping Crane migration studies 1981–82. Pages 371–379 *in* G. Archibald and R. Pasquier, editors, Proceedings of the 1983 International Crane Workshop. International Crane Foundation, Baraboo, WI.

KUYT, E. 1992. Aerial radio-tracking of Whooping Cranes migrating between Wood Buffalo National Park and Aransas National Wildlife Refuge, 1981–84. Canadian Wildlife Service, Occasional Paper No. 74.

LEWIS, J.C. 1979. Taxonomy, food, and feeding habitat of Sandhill Cranes, Platte Valley, Nebraska. Pages 21–27 *in* J.C. Lewis, editor, Proceedings 1978 Crane Workshop. Colorado State University Press, Fort Collins, CO.

LEWIS, T.E., AND R.D. SLACK. 2008. Whooping Cranes and human disturbance: an historical perspective

and literature review. Proceedings of the North American Crane Workshop 10:3–6.

Lingle, G.R., G.A. Wingfield, and J.W. Ziewitz. 1991. The migration ecology of Whooping Cranes in Nebraska, USA. Pages 395–401 *in* J. Harris, editor, Proceedings of the 1987 International Crane Workshop. International Crane Foundation, Baraboo, WI.

Long, S.L., and N.A. Azmi. 2017. Using photographic identification to monitor sea turtle populations at Perhentian Islands Marine Park in Malaysia. Herpetological Conservation and Biology 12:350–366.

Meine, C.D., and G.W. Archibald. 1996. The cranes: status survey and conservation action plan. International Union for Conservation of Nature (IUCN), Gland, Switzerland.

Mergler Niemeier, M.M., and P.E. Niemeier. 1982. Possible evidence of fish-eating by a Lesser Sandhill Crane from the Central Platte Valley, Nebraska. Nebraska Bird Review 50:42–44.

Newton, I. 2006. Can conditions experienced during migration limit population levels of birds. Journal of Ornithology 147:146–166.

Niemuth, N.D., A.J. Ryba, A.T. Pearse, S.M. Kvas, D.A. Brandt, B. Wangler, J.E. Austin, and M.J. Carlisle. 2018. Opportunistically collected data reveal habitat selection by migrating Whooping Cranes in the US Northern Plains. Condor 120:343–356.

Novakowski, N.S. 1966. Whooping Crane population dynamics on the nesting grounds, Wood Buffalo National Park, Northwest Territories, Canada. Canadian Wildlife Service, Ottawa, Canada, Research Report Series No. 1.

Page, L.M., and B.M. Burr. 2011. Peterson field guide to freshwater fishes. 2nd edition. Houghton Mifflin Company, Boston, MA.

Pearse, A.T., M.J. Harner, D.M. Baasch, G.D. Wright, A.J. Caven, and K.L. Metzger. 2017. Evaluation of nocturnal roost and diurnal sites used by Whooping Cranes in the Great Plains, USA. U.S. Geological Survey, Open-File Report 2016-1209.

Pearse, A.T., M. Rabbe, L.M. Juliusson, M.T. Bidwell, L. Craig-Moore, D.A. Brandt, and W. Harrell. 2018. Delineating and identifying long-term changes in the Whooping Crane (*Grus americana*) migration corridor. PLOS ONE 13:e0192737.

Phelps, Q.E., S.J. Tripp, J.E. Garvey, D.P. Herzog, R.A. Hrabik, D.E. Ostendorf, J.W. Ridings, and J.W. Crites. 2011. Juvenile channel catfish habitat use in the Middle Mississippi River. American Fisheries Society Symposium 77:1–9.

Pimm, S.L., S. Alibhai, R. Bergl, A. Dehgan, C. Giri, Z. Jewell, L. Joppa, R. Kays, and S. Loarie. 2015. Emerging technologies to conserve biodiversity. Trends in Ecology and Evolution 30:685–696.

Power, M.E. 1984. Depth distributions of armored catfish: predator induced resource avoidance? Ecology 65: 523–528.

[RWBJV] Rainwater Basin Joint Venture. 2017. Digital Image Library. Grand Island, NE.

Sherfy, M.H., M.J. Anteau, T.L. Shaffer, M.A. Sovada, and J.H. Stucker. 2012. Foraging ecology of Least Terns and Piping Plovers nesting on Central Platte River sandpits and sandbars. U.S. Geological Survey Open-File Report 2012-1059

Smith, N.D. 1971. Transverse bars and braiding in the Lower Platte River, Nebraska. Geological Society of America Bulletin 82:3407–3420.

Sotiropoulos, M. 2002. Analysis of pond food webs in Whooping Crane nesting area, Wood Buffalo National Park. Master's thesis, University of Alberta, Edmonton, Canada.

Stahlecker, D.W. 1992. Using National Wetlands Inventory maps to quantify Whooping Crane stopover habitat in Oklahoma. Proceedings of the North American Crane Workshop 6:62–68.

Stahlecker, D.W. 1997. Availability of stopover habitat for migrant Whooping Cranes in Nebraska. Proceedings of the North American Crane Workshop 7: 132–140.

Stickley, A.R. 1995. Impact of Great Blue Heron depredations on channel catfish farms. Journal of the World Aquaculture Society 26:194–199.

Strobel, B.N., and J.M. Butler. 2014. Monitoring Whooping Crane abundance using aerial surveys: influences on detectability. Wildlife Society Bulletin 38:188–195.

Uhler, F., and L. Locke. 1970. A note on the stomach contents of two Whooping Cranes. Condor 72: 246–246.

[USFWS] United States Fish and Wildlife Service. 1978. Title 50, Wildlife and Fisheries: Part 17, Endangered and Threatened wildlife and plants, determination of critical habitat for the Whooping Crane. Federal Register 43:20938–20942.

[USFWS] United States Fish and Wildlife Service. 1981. The Platte River ecology study: special research report. Northern Prairie Wildlife Research Center, Jamestown, ND.

[USFWS and NGPC] United States Fish and Wildlife Service and Nebraska Game and Parks Commission. 2015. Requirements for avoiding disturbance/harassment to migrating Whooping Cranes. https://outdoornebraska.gov/wp-content/uploads/2015/11/PDF_C_WhoopingCraneDisturbanceGuidelines_11052015.pdf

[USGS] United States Geological Survey. 2018. National water information system: web interface. Streamflow-gaging stations: USGS 06805500 Platte River at Louisville, NE, and USGS 06796500 Platte River near Leshara, NE.

Walden-Schreiner, C., S. Rossi, A. Barros, C. Pickering, and Y. Leung. 2018. Using crowd-sourced photos to assess seasonal patterns of visitor use in mountain-protected areas. Ambio 47:781–793.

Weather Underground. 2018. Historical weather for Hastings Municipal Station, Hastings, NE, from 22 March 2018. [Accessed 25 July 2018]. https://www.wunderground.com/history/daily/us/ne/hastings/KHSI/date/2018-3-22

Weise, F.J., V. Vijay, A.P. Jacobson, R.F. Schoonover, R.J. Groom, J. Horgan, D. Keeping, R. Klein, K. Marnewick, G. Maude, and J. Melzheimer. 2017. The distribution and numbers of cheetah (*Acinonyx jubatus*) in southern Africa. PeerJ 5:e4096.

Werner, S.J., M.E. Tobin, and P.B. Fioranelli. 2001. Great Egret preference for catfish size classes. Waterbirds 24:381–385.

Westwood, C.M., and F. Chávez-Ramírez. 2005. Patterns of food use of wintering Whooping Cranes on

the Texas coast. Proceedings of the North American Crane Workshop 9:133–140.

WHILES, M.R., C.K. MEYER, AND S. BAER. 2010. Biological evaluation of Central Platte River slough wetland restorations. Final Report (no. 191B), The Nebraska Game and Parks Commission, Lincoln, NE; The United States Fish and Wildlife Service, Grand Island, NE; and the Platte River Whooping Crane Maintenance Trust, Wood River, NE.

WILLARD, D.E. 1977. The feeding ecology and behavior of five species of herons in southeastern New Jersey. Condor 79:462–470.

WILLIAMS, G.P. 1978. The case of the shrinking channels: the North Platte and Platte Rivers in Nebraska. Circulars of the United States Geological Survey 781: 1–48.

WILSON, E.C., W.A. HUBERT, AND S.H. ANDERSON. 1993. Nesting and foraging of Least Terns on sand pits in central Nebraska. Southwestern Naturalist 38:9–14.

ZIMORSKI, S.E., T.L. PERKINS, AND W. SELMAN. 2013. Chelonian species in the diet of reintroduced Whooping Cranes (*Grus americana*) in Louisiana. Wilson Journal of Ornithology 125:420–423.

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