10-10-2018

Spatial analysis of borrow pits along the Platte River in south-central Nebraska, USA, in 1957 and 2016

Nicole M. Pauley

University of Nebraska at Kearney, pauleynm2@lopers.unk.edu

Mary J. Harner

University of Nebraska at Kearney, harnermj@unk.edu

Emma M. Brinley Buckley

University of Nebraska at Kearney, brinleybuckleyem@unk.edu

Paul R. Burger

University of Nebraska at Kearney, burgerpr@unk.edu

Keith Geluso

University of Nebraska at Kearney, gelusok1@unk.edu

Follow this and additional works at: <http://digitalcommons.unl.edu/tnas>

Part of the [Environmental Monitoring Commons](#), [Natural Resources and Conservation Commons](#), [Natural Resources Management and Policy Commons](#), [Terrestrial and Aquatic Ecology Commons](#), and the [Water Resource Management Commons](#)

Pauley, Nicole M.; Harner, Mary J.; Brinley Buckley, Emma M.; Burger, Paul R.; and Geluso, Keith, "Spatial analysis of borrow pits along the Platte River in south-central Nebraska, USA, in 1957 and 2016" (2018). *Transactions of the Nebraska Academy of Sciences and Affiliated Societies*. 518.

<http://digitalcommons.unl.edu/tnas/518>

This Article is brought to you for free and open access by the Nebraska Academy of Sciences at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Transactions of the Nebraska Academy of Sciences and Affiliated Societies by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Spatial analysis of borrow pits along the Platte River in south-central Nebraska, USA, in 1957 and 2016

Nicole M. Pauley,¹ Mary J. Harner,^{1,2*} Emma M. Brinley Buckley,² Paul R. Burger,³ and Keith Geluso¹

¹ Department of Biology, University of Nebraska at Kearney, Kearney, Nebraska 68849, USA

² Department of Communication, University of Nebraska at Kearney, Kearney, Nebraska 68849, USA

³ Department of Geography, University of Nebraska at Kearney, Kearney, Nebraska 68849, USA

*Corresponding author: Mary J. Harner, Department of Biology and Department of Communication, University of Nebraska at Kearney, Kearney, Nebraska 68849; tel (308) 865-8639; email harnermj@unk.edu

Abstract: The Central Platte River Valley (CPRV) of Nebraska provides critical habitat for wildlife, while serving agricultural, industrial, and other human uses. Mining of sand and gravel from the floodplain of the Platte River has supported construction of roads and other uses, and this extraction has created many borrow-pit ponds, lakes, and other small bodies of standing water (hereafter borrow-pits), further transforming riparian and prairie habitats. The objective of this study was to compare the abundance, size, and distribution of borrow pits before construction of Interstate 80 (1957) and at present (2016) from Lexington to Chapman, Nebraska, a length of river spanning about 146 km (90 mi) and sometimes referred to as the Big Bend Reach. Orthorectified aerial imagery of the Platte River was obtained for years 1957 and 2016, and we digitized the standing bodies of water within the floodplain in ArcGIS. Total numbers of borrow pits and measures of pit shape were calculated and compared between floodplain regions where imagery overlapped. From 1957 to 2016, the number of borrow pits increased from 300 to 786, total area occupied by pits expanded by 538%, and total shoreline of pits increased by 261%. In 2016, aerial imagery was available for a larger extent of the floodplain and contained a total of 1,062 borrow pits covering 16 km² (6 mi²), with a total shoreline of 581 km (361 mi). For context, the Platte River channels' approximate area was 45 km² (17 mi²) and shoreline 1,582 km (983 mi) between Lexington and Chapman, Nebraska, in 2016. Results provide insight into historical and current presence, distribution, and shape of borrow pits along the Platte River, as well as serve as a reference point for future studies investigating regional landscape change and ecological effects of creating hundreds of borrow pits on the floodplain.

Keywords: gravel pit, borrow pit, river mining, pond, lake, Platte River, GIScience

doi: 10.13014/K29021ZK

Introduction

The Platte River and surrounding floodplain ecosystems in south-central Nebraska, USA, sustain diverse natural and human systems. The region provides critical habitat for several endangered and threatened species (National Research Council 2005), including the Whooping Crane (*Grus americana*), Interior Least Tern (*Sternula antillarum athalassos*), and Piping Plover (*Charadrius melodus*). The river and its floodplain are spring migratory stopover sites for 500,000–600,000 Sandhill Cranes (*Antigone canadensis*) (Kinzel et al. 2006, Krapu et al. 2014, Liddick 2017). The Platte River and nearby Rainwater Basin wetland region also serve as spring-staging areas in the Central Flyway for millions of individuals representing a number of waterfowl species, including Mallards (*Anas platyrhynchos*), Northern Pintails (*Anas acuta*), Greater White-fronted Geese (*Anser albifrons*), Lesser Snow Geese (*Chen caerulescens*), and Ross's Geese (*Chen rossii*) (Gersib et al. 1992, Vrtiska and Sullivan 2009, Jorgensen 2012). Sur-

rounding wet meadows, a remnant prairie ecosystem, are inhabited by a diversity of flora and fauna (Helzer and Jelinski 1999, Henszey et al. 2004, Kim et al. 2008, Meyer and Whiles 2008, Geluso and Harner 2013, Caven et al. 2017). Water resources of central Nebraska also sustain one of the largest expanses of irrigated agriculture in the United States (USDA 2012), while serving other municipal and industrial uses. Associated hydrological depletions and changes in timing of river flows have had cascading effects on the river ecosystem (e.g., Williams 1978, Eschner et al. 1983). These effects include reductions in channel widths and sediment loads, altered groundwater elevations, changes in distributions of riparian vegetation, and loss of wildlife habitat (Williams 1978, Sidle et al. 1989, Johnson 1994 and 1997, Currier 1997, National Research Council 2005).

Mining of sand and gravel from the floodplain also has altered the ecosystem of the Platte River. Construction of Interstate 80 (I-80) across Nebraska, which occurred from 1955–1974 (History Nebraska 2018), increased demand

for construction materials and resulted in creation of over a hundred large, unnatural borrow pits along the Platte River in central Nebraska (Burchett 1971, McCarraher et al. 1974). Many borrow pits were developed with the intent of managing fisheries and public access locations for recreation in cooperation with the Nebraska Game and Parks Commission, and more than 50 of them became known as the “I-80 lakes”, with most open to the public (McCarraher et al. 1974, Eades 2006, Eifert 2013). As regional development supported a growing need for construction materials, borrow pits continued to be dredged to meet demands. In 2013, nonfuel mineral production in Nebraska was valued at \$166 million, with construction sand and gravel, as well as crushed stone, leading production (USGS 2016). Despite the intensity of borrow pit development within the CPRV, there has yet to be a comprehensive assessment of resultant landcover change. The transformation of riparian and prairie landscapes into borrow pits likely has implications for the overall ecology of the system. Therefore, we used geographic information science (GIScience) and historical aerial imagery to determine the abundance, size, and distribution of borrow pits along the Platte River in south-central Nebraska before construction of Interstate 80 (1957) and at present (2016). This analysis enabled us to better understand how borrow pits have changed through time and their potential role in the ecology of an important and diverse reach of the Platte River.

Methods

We examined borrow-pit ponds, lakes, and other small bodies of standing water (hereafter borrow pits) in the Central Platte River Valley (CPRV), focusing from Lexington to Chapman, Nebraska, an area also referred to as the Big Bend Reach. This reach spans about 146 km across nine counties (Adams, Buffalo, Dawson, Gosper, Hall, Hamilton, Kearney, Merrick, and Phelps) and encompasses 12 segments of floodplain traversed by bridges (Fig. 1). Aerial imagery was obtained for years 1957 and 2016. The 1957 imagery was a single band black and white in the visible spectrum, with 25-cm (10-in) spatial resolution, originally obtained between 21 May and 30 August 1957 by the United States Department of Interior and published by the Rainwater Basin Joint Venture (Grand Island, NE, USA). High-resolution imagery from 2016 was 3-band (green, red, NIR) color infrared standard false-color composite with 15-cm (6-in) spatial resolution taken between 17-21 June 2016 and obtained from the Platte

River Recovery Implementation Program (Kearney, NE, USA). Both sets of imagery were ortho-rectified prior to use. Analyses were conducted in ArcGIS 10.4.1 (Environmental Systems Research Institute, Redlands, CA, USA).

The floodplain of the Platte River was used as the boundary of the study area from Lexington to Chapman, Nebraska. To determine the floodplain boundary, a Soil Survey Geographic Database (SSURGO) floodplain shapefile was obtained for the state of Nebraska, where land was classified into polygons based on likelihood of flooding (NRCS 2017). Outer edges of the floodplain were digitized, including polygons where flooding was designated ‘Frequent’, ‘Occasional’, ‘Rare’, and ‘Very Rare’, while the remainder of the land was excluded. Spatial data layers were projected into NAD 1983 (2011) StatePlane Nebraska FIPS 2600 (US Feet) to preserve distance and area calculations. Imagery from 1957 and 2016 was clipped to the spatial extent of the floodplain boundary to ensure that the same geographic extent was used for both years. A portion of the floodplain was missing in the 1957 imagery, so only the 1957 extent of imagery was used for comparisons.

To classify borrow pits in the imagery, standing bodies of water with any part located within the floodplain were digitized at a scale of 1:1,000. Differences in the amount of aquatic vegetation, pit depth, and water turbidity were all factors that changed the appearance of borrow pits in the imagery. Therefore, care was taken to digitize all pits considering these factors, but some potentially were overlooked or misclassified. All parts of pits with emergent vegetation and thick algal biofilms were included within pit delineations. Flowing water features such as river channels, sloughs, and irrigation canals were not digitized for the analysis. We made multiple passes at varying spatial scales across the entire extent of the study area to ensure successful tracing of borrow pits.

Number, area, and perimeter of digitized borrow pits were calculated for the 1957 and 2016 imagery. Total number of pits were summed by bridge segment (Fig. 1). We summed the area of all shapes delineating borrow pits to calculate the total amount of floodplain occupied by them. Similarly, we summed the total perimeters of shapes delineating borrow pits to determine the total perimeter of borrow pits on the floodplain. Finally, we divided the perimeter by the area of each borrow pit to determine perimeter to area ratio and then calculated the mean ratio for both years. Comparisons of borrow pits in the floodplain between the 1957 imagery and 2016 imagery were based on the spatial extent of imagery that overlapped between years. Descriptive statistics also were cal-

Figure 1. Study area in the Central Platte River Valley, between Lexington and Chapman, Nebraska. The floodplain, derived from a Soil Survey Geographic Database (SSURGO) shapefile, is outlined in black and divided by bridge segments 1-12, with corresponding segment names described in Table 2. The imagery extent coincident to both 1957 and 2016 is displayed in gray.

culated for borrow pits in the floodplain for the full extent of the 2016 imagery to serve as a baseline for future studies of land-use change within the CPRV. Finally, the area and channel margins of the Platte River were summarized in the 2016 imagery to place the area and perimeter of borrow pits into context of other regional water sources. We classified active river channels within the floodplain boundary using interactive, supervised classification. The raw classification output was corrected using the majority filter and boundary clean tool in ArcGIS Analysis toolbox, as well as manual inspection.

Results

In 1957, 300 borrow pits were present along the CPRV, covering an area of 1.91 km² with a total perimeter (shore-line) of 122 km (Table 1). By 2016, the number of borrow pits had more than doubled, increasing to 786 pits in the portion of floodplain that overlapped with the 1957 imagery (Table 1). The range in area of borrow pits increased between 1957 and 2016 (Table 1), indicating a substantial increase in the size of some pits in addition to an increase in the overall number of pits on the floodplain. Total area

Table 1: Description of number, area, and perimeter of borrow pits in the floodplain of the Central Platte River Valley, Nebraska, in 1957 and 2016. Results from 2016 are presented for extent of imagery that overlapped with 1957 imagery, as well as for the larger portion of the floodplain that was available in 2016 imagery only.

Shape descriptor	1957	2016 (Overlap with 1957)	2016 (Full extent)
Total number (<i>n</i>)	300	786	1,062
Range in area (m ²)	56-54,631	57-348,426	57-349,284
Mean area (m ² ; $\bar{X} \pm \text{SD}$)	6,391 $\pm$ 9,025	15,511 $\pm$ 33,464	15,434 $\pm$ 33,872
Total area (km ²)	1.91	12.19	16.4
Total perimeter (km)	122	440	581
Perimeter (km) to Area (km ²) ratio ($\bar{x} \pm \text{SD}$)	124 $\pm$ 91	117 $\pm$ 95	111 $\pm$ 85

occupied by borrow pits and total perimeter (shoreline) expanded by 538% and 261%, respectively from 1957 to 2016 (Table 1). Perimeter to area ratios, on average, were similar between years. Qualitatively, pits varied from nearly circular shapes to complex coiling shapes with many extensions. Of the borrow pits that existed in 1957, few remained the same shape and size by 2016; some pits were expanded upon, while others were filled (Fig. 2). Overall patterns across the floodplain showed an abundance of borrow pits near I-80 interchanges south of towns and cities (Fig. 2).

Conservation managers and biologists often use bridge segments of the CPRV as benchmarks (Fig. 1; Kinzel et al. 2006, Krapu et al. 2014), therefore we also examined changes in the number and area of borrow pits by bridge segment in the region of floodplain where imagery overlapped between years (Table 2, Fig. 3). The total number and total area of borrow pits increased in all bridge segments from 1957 to 2016, but the number of pits and area did not always increase proportionally (Table 2). The

greatest increases in number of pits occurred in bridge segments 12 (Overton) and 7 (Gibbon), and the greatest increases in area occurred in segments 7 (Gibbon) and 9 (Kearney) (Table 2, Fig. 3). The least amount of change in both number of pits and area was within bridge segment 8 (HWY 10), where pits already had been well-developed by 1957 (Table 2). In 1957, 27% of borrow pits were in the vicinity of Grand Island (segments 1-3) and another 25% around Kearney (segments 8-9), and in 2016, about 25% were around Grand Island, 21% around Kearney, and 15% near Gibbon (segments 6-7) (Table 2).

Imagery from 2016 provided nearly full coverage for the floodplain that was not entirely available for 1957. Characterization of borrow pits over this larger area revealed 1,062 pits with a total perimeter of 581 km and a total area of 16.4 km², representing 1.8% of the entire floodplain area of the CPRV (Table 1, Fig. 4). For context, the Platte River's approximate shoreline perimeter was 1,582 km and the channel area was 45 km² between Lexington and Chapman, Nebraska, in 2016 (Fig. 4). Of these com-

Table 2. Total number and area of borrow pits and percentage increases by bridge segment in the floodplain of the Central Platte River Valley in 1957 and 2016 for portions of imagery that overlapped between years.

Bridge Segment	Location	Number of Pits			Area of Pits (km ²)		
		1957	2016	Percent Change	1957	2016	Percent Change
1	Chapman	28	83	196%	0.09	0.43	383%
2	HWY 34	35	61	74%	0.14	0.85	507%
3	HWY 281	18	54	200%	0.14	1.27	807%
4	Alda	10	34	240%	0.08	0.30	261%
5	Wood River	29	51	76%	0.09	0.48	452%
6	Shelton	19	64	237%	0.08	0.50	510%
7	Gibbon	13	55	323%	0.05	0.79	1480%
8	HWY 10	54	82	52%	0.61	1.85	203%
9	Kearney	22	81	268%	0.14	1.83	1207%
10	Odessa	27	65	141%	0.19	1.21	537%
11	Elm Creek	26	68	162%	0.13	1.23	846%
12	Overton	19	88	363%	0.17	1.45	753%

Figure 2. The 1957 and 2016 imagery over a 10.6 km² area south of four places within the study area, displayed at a scale of 1:65,000. Imagery from 1957 is a single band black and white in the visible spectrum with 25-cm (10-in) spatial resolution captured by the United States Department of Interior. Imagery from 2016 is a 3-band color infrared standard false-color composite at 15-cm (6-in) resolution obtained by the Platte River Recovery Implementation Program. The comparison displays digitized pits from 1957 (blue) and 2016 (yellow) with the areas of overlap highlighted (green).

Figure 3. Percentage increase in pit area from 1957 to 2016 in the floodplain of the Central Platte River Valley, displayed by bridge segment with corresponding names found in Table 2. City limits of Lexington, Kearney, Gibbon, Grand Island, and Chapman are shown in orange with borrow pit locations in 2016 highlighted in yellow.

Figure 4. Borrow pits (yellow) and river channels (blue) in the floodplain of the Central Platte River Valley for the full extent of the 2016 imagery. Inset maps at a scale of 1:80,000 show variety in size and complexity of pits, from more rectangular pits to large complex, coiling shapes at four different locations near Interstate-80 and the Platte River.

Figure 5. Total area of borrow pits (km²) by bridge segment, with corresponding names in Table 3, in the floodplain of the Central Platte River Valley for the full extent of the 2016 imagery. City limits of Lexington, Kearney, Gibbon, Grand Island, and Chapman are shown in orange with borrow pit locations in 2016 highlighted in yellow.

bined aquatic habitats, borrow pits represented about 27% of aquatic-terrestrial margin or shoreline and about 27% of surface water area. The largest total areas occupied by borrow pits were in bridge segments near the cities of Grand Island and Kearney, NE (Fig. 5), while the highest numbers of pits were observed near Grand Island, NE, in the Chapman and HWY 281 bridge segments (Table 3).

Table 3. Total number of borrow pits by bridge segment in the floodplain of the Central Platte River Valley in 2016 for the full extent of imagery.

Bridge Segment	Location	Number of Pits
1	Chapman	162
2	HWY 34	85
3	HWY 281	100
4	Alda	65
5	Wood River	92
6	Shelton	78
7	Gibbon	76
8	HWY 10	94
9	Kearney	83
10	Odessa	69
11	Elm Creek	68
12	Overton	90

Discussion

Our study provided insight into the historical and current presence, size, and distribution of borrow-pit ponds, lakes and other small bodies of standing water in the floodplain of the Platte River in south-central Nebraska. We observed that borrow pits were already well established on the Platte River's floodplain in 1957 before construction of I-80, but the number of borrow pits, total area occupied by pits, and shoreline (perimeter) of pits increased dramatically from 1957 to 2016. In summer 2016, borrow pits constituted over a quarter of the shoreline and area of surface water on the floodplain, based on river channels and borrow pits combined, but generally excluding other waters like sloughs and irrigation ditches. By examining both change in pit number and pit area, we were able to better understand where and how borrow pit growth had occurred. We observed disproportionate changes in pit area relative to pit number for some bridge segments that might have been caused by expansion or filling of pits present in 1957 and/or variation in the size of pits developed between years. By 2016, the largest total areas of borrow pits were in bridge segments near cities in Hall and Buffalo counties. These counties experienced population increases in recent decades, with the population of Hall County expanding from 32,186 to 61,705 and Buffalo County expanding from 25,134

to 49,383 between 1950 and 2016 (Drozd and Deichert 2007, United States Census Bureau 2018).

Patterns in pit distribution showed that most pits were in close proximity to the Platte River and I-80, and many pits were situated around interstate interchanges near towns. McCarraher et al. (1974) reported that 116 large borrow pits were pumped and dredged from east of Grand Island to Ogallala, Nebraska, for material used in the construction of I-80 and its interchanges. The construction of such a large piece of infrastructure across the region likely had a significant impact on the number of pits dug; however, presence of pits in the 1957 imagery indicated that some borrow pits were developed prior to the construction of the interstate. Water bodies that we classified as borrow pits spanned a wide-range of sizes and included smaller ponds than those analyzed by McCarraher et al. (1974), who focused on borrow pits ranging in size from 2.2 to 21.2 ha and depth from 1.8 to 7.3 m. Both studies indicate that these waterbodies are extensive along the Platte River's floodplain in south-central Nebraska, where pumping and dredging of pits continues. Feasibility of digging, ease of reaching a transportation network, and proximity to demand for construction material likely have been involved in decisions to develop pits. Such factors remain critical in decision-making related to pumping and dredging of borrow pits today, as humans continue to alter and use resources of the Platte River system.

Anthropogenic land-use change resulting from the excavation of borrow pits altered the landscape and formed an expansive new type of wetland in the Platte River's floodplain with both negative and positive implications. Conversion of riparian forests, grasslands, or cropland to open ponds from mining has affected ecosystems in various ways. In some systems, borrow pits and associated dikes and levees may cut off river channels from the floodplain and constrict the river corridor, with cascading effects on geomorphology, sediment transport, hydrology, water quality, and aquatic habitat (Hilldale and Klawon 2005 and references therein). Mining of sand and gravel from native grasslands often has deleterious ecological effects, including loss of native wet meadows, altered soil composition and seed banks, increased risk of colonization by invasive plant species, and decreased native plant biodiversity (Bradshaw 1983, Prosser and Roseby 1995, Lozon and MacIsaac 1997, LaGrange 2005). Conversely, gravel pits have been found to provide valuable wildlife habitat (e.g., Svedarsky and Crawford 1982, Matter and Mannan 1988 and references therein). For example, new aquatic, shoreline, and island habitats created

from gravel mining can support high diversity and densities of birds (Milne 1974, Catchpole and Tydeman 1975, Landin and Soots 1978, Giroux 1981, Santoul et al. 2004). On the Platte River, borrow pits contribute nesting habitat for federally protected Least Terns and Piping Plovers (Kirsch 1996, LaGrange 2005, Brown et al. 2016), and some are actively managed as off-channel nesting sites for conservation (Baasch et al. 2017). Borrow pits along the Platte River also provide aquatic habitat for fish, including Channel Catfish (*Ictalurus punctatus*), Largemouth Bass (*Micropterus salmoides*), and Bluegill (*Lepomis macrochirus*) (Lundgren et al. 2012); aquatic-terrestrial ecotones used by vertebrates, including amphibians, small mammals, reptiles, and birds (see species list in Lundgren et al. 2012); and open water for species like Snow Geese, Mallards, American White Pelicans, egrets, and herons (Landin and Soots 1978, Giroux 1981, Vrtiska and Sullivan 2009). However, deep water and steep banks of some borrow pits may not appeal to wading birds, dabbling ducks, and other waterbirds, like cranes, that utilize shallow wetlands (Colwell and Taft 2000). It is unclear whether additional habitat provided by these pits can help compensate for loss of natural riparian habitats in the CPRV, and further studies examining biological communities associated with borrow pits and their shorelines would be informative.

Broader ecological effects of borrow pits, alone and in combination with other alterations within the CPRV, warrant additional study. Investigations from other regions with sand and gravel mining may help inform prioritization of questions and development of hypotheses. Examples of questions that need further investigation on the CPRV include: i) What are the primary uses of inactive borrow pits (development, recreation, abandonment, etc.), and how does this use affect how pits undergo ecological succession (e.g., Milne 1974, Řehouňková and Prach 2008)?; ii) What strategies may be employed to conserve remaining wet-meadow, riparian, and grassland habitats when planning for future mining, and how may abandoned borrow pits be reclaimed to help restore some of the habitat that has been lost (Svedarsky and Crawford 1982)?; iii) How do borrow pits affect birds in the CPRV during spring migration? Human-excavated lakes provide roosting sites for geese distributed close to agricultural fields that may exacerbate competition for waste grains with river-roosting cranes (Anteau et al. 2011, Pearse et al. 2010). These waters also may concentrate birds and play a role in transmission of disease (e.g., avian cholera, Zinkl et al. 1977) and other pathogens carried by cranes and water-

fowl (Moser 2014); iv) How much evaporative water loss occurs from borrow pits in relation to the overall regional water budget, and how do hydrologic fluctuations affect water quality, notably salinity levels, pH, and temperature (e.g., Mollema et al. 2015)?; v) How do landscape-level changes in the distribution of surface water and the shape of those water bodies (i.e. linear river channels compared to circular borrow pits) affect the overall ecology of the Platte River and processes occurring at aquatic-terrestrial interfaces, like nutrient cycling and transport?

The effect of borrow pits is an issue that transcends the Platte River. Globally, similar types of pits exist as a result of various surface mines created close to the water table (e.g., Milne 1974, Catchpole and Tydeman 1975, Neumann et al. 1994, Kondolf et al. 2002, Hilldale and Klawon 2005, Řehouňková and Prach 2008, Mollema et al. 2015, Zhao et al. 2016). Although originally excavated for extraction of materials, such as limestone, clay, or sand and gravel, many lakes now serve other purposes after material extraction (Antosch 1984, Matter and Mannan 1988, Baasch et al. 2017). For example, numerous pits in the CPRV, as well as other Midwestern states such as Iowa, South Dakota, Colorado, and Kansas, have been transformed into recreation areas often stocked with game fish and are frequently viewed as scenic and recreational improvements (Taub et al. 1974, Antosch 1984, Svedarsky and Crawford 1982). In Europe, borrow pits within floodplains of the Rhine and Garonne rivers provide recreational opportunities, in addition to beneficial substitutional habitat for plankton, fish, and waterbirds (Neumann et al. 1994, Santoul et al. 2004, Zhao et al. 2016). Because borrow pits are created in numerous places and have varying functional purposes around the world, their ecological role and implications for wildlife remain an area for further assessment (e.g., Kerbiriou et al. 2018). Our research represents a case-study of a larger phenomenon, provides a baseline for management as well as future research on borrow pits in the CPRV, and contributes to the literature worldwide. As more borrow pits will continue to be dredged to meet population growth and construction demand, understanding the resultant extent and spatial variation of modifications to the landscape and the ecological implications is necessary to guide management decisions, including prioritizing areas to protect grassland or create wildlife habitat. Understanding the broader effects of borrow pits from interdisciplinary viewpoints, with consideration for ecological, economic, recreational, and social values, can aid in management and protection of areas vital to humans and wildlife.

Acknowledgments — We thank the Rainwater Basin Joint Venture and Platte River Recovery and Implementation Program for providing ortho-rectified aerial imagery of the study area for 1957 and 2016, respectively. We thank two reviewers for constructive comments, as well as editor B. Chase for handling the manuscript. Funding came from the Undergraduate Research Fellows Program at the University of Nebraska at Kearney (UNK). We thank members of the River Time Lab at UNK for support throughout the project.

Literature Cited

- Anteau MJ, Sherfy MH, and Bishop AA. (2011) Location and agricultural practices influence spring use of harvested cornfields by cranes and geese in Nebraska. *Journal of Wildlife Management* 75(5): 1004-1011.
- Antosch LM. (1984) Surface mine lakes: an important water resource for Iowa. *Proceedings of the Iowa Academy of Science* 91(2): 67-69.
- Baasch DM, Farrell PD, Farnsworth JM, and Smith CB. (2017) Nest-site selection by Interior Least Terns and Piping Plovers at managed, off-channel sites along the Central Platte River in Nebraska, USA. *Journal of Field Ornithology* 88(3): 236-249.
- Bradshaw AD. (1983) The reconstruction of ecosystems: presidential address to the British Ecological Society, December 1982. *Journal of Applied Ecology* 20: 1-17.
- Brown MB, Dinan LR, and Jorgensen JG. (2016) 2016 Interior Least Tern and Piping Plover monitoring, research, management, and outreach report for the Lower Platte River, Nebraska. Joint report of the Tern and Plover Conservation Partnership and the Nongame Bird Program of the Nebraska Game and Parks Commission, Lincoln, NE. 46 pp.
- Burchett RR. (1971) *Directory of Nebraska quarries, pits, and mines*. Resource Report Number 5. University of Nebraska Conservation and Survey Division, Lincoln, NE. 75 pp.
- Catchpole CK and Tydeman CF. (1975) Gravel pits as new wetland habitats for the conservation of breeding bird communities. *Biological Conservation* 8(1): 47-59.
- Caven AJ, King KC, Wiese JD, and Brinley Buckley EM. (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.
- Colwell, MA and Taft OW. (2000) Waterbird communities in managed wetlands of varying water depth. *Waterbirds* 23(1):45-55.
- Currier PJ. (1997) Woody vegetation expansion and continuing declines in open channel habitat on the Platte River in Nebraska. *Proceedings of the North American Crane Workshop*. 7: 141-152.

- Drozdz DJ and Deichert J. (2007) *Nebraska historical population report*. Retrieved from the Internet 10 May 2018: <https://digitalcommons.unomaha.edu/cparpublications/37/>
- Eades R. (2006) *Fishing across Nebraska: a guide to public fishing lakes in the I-80 corridor*. NEBRASKAland May 2006: 20-33. Retrieved from the Internet 10 May 2018: <http://digital.outdoornebraska.gov/i/333605-fishing-across-nebraska-i-80-corridor/13?m4=>
- Eifert B. (2013) *Interstate 80 Lakes – Grand Island to Elm Creek: fish survey results – Spring 2013*. Interstate 80 Lakes Fish Population Survey. Nebraska Game & Parks Commission. 16 pp. Retrieved from the Internet 18 May 2018: <https://outdoornebraska.gov/wp-content/uploads/2015/10/I80-Lakes-Grand-Island-to-Elm-Creek-2013.pdf>.
- Eschner TR, Hadley RF, and Crowley KD. (1983) *Hydrologic and morphologic changes in channels of the Platte River Basin in Colorado, Wyoming, and Nebraska: a historical perspective*. United States Geological Survey Professional paper 1277-A. 39 pp.
- Geluso K and Harner MJ. (2013) Reexamination of herpetofauna on Mormon Island, Hall County, Nebraska, with notes on natural history. *Transactions of the Nebraska Academy of Science* 33: 7-20.
- Gersib RA, Dinan KF, Kauffeld JD, Onnen MD, Gabig PJ, Cornely JE, Jasmer GE, Hyland JM, and Strom KJ. (1992) *Looking to the Future: An Implementation Plan for the Rainwater Basin Joint Venture*. Nebraska Game and Parks Commission, Lincoln, NE. 56 pp.
- Giroux JF. (1981) Use of artificial islands by nesting waterfowl in southeastern Alberta. *The Journal of Wildlife Management* 45(3): 669-679.
- Helzer CJ and Jelinski DE. (1999) The relative importance of patch area and perimeter-area ratio to grassland breeding birds. *Ecological Applications* 9(4): 1448-1458.
- Henszey RJ, Pfeiffer K, and Keough JR. (2004) Linking surface- and ground-water levels to riparian grassland species along the Platte River in central Nebraska, USA. *Wetlands* 24(3): 665-687.
- Hilldale RC and Klawon J. (2005) *Rehabilitation of floodplain mining pits: interim report detailing initial plans and procedures*. Bureau of Reclamation Science and Technology Interim Report. Technical Service Center, Denver, CO. 33 pp.
- History Nebraska. (2018) *Marker Monday: The Golden Link*. Nebraska State Historical Society Blog. Retrieved from the Internet 16 May 2018: <https://history.nebraska.gov/blog/marker-monday-golden-link-0>
- Johnson WC. (1994) Woodland expansions in the Platte River, Nebraska: patterns and causes. *Ecological Monographs* 64(1): 45-84.
- Johnson WC. (1997) Equilibrium response of riparian vegetation to flow regulation in the Platte River, Nebraska. *Regulated Rivers: Research and Management* 13: 403-415.
- Jorgensen JG. (2012) *Birds of the Rainwater Basin, Nebraska*. Nebraska Game and Parks Commission, Lincoln, NE. 121 pp.
- Kerbiriou C, Parisot-Laprun M, and Julien JF. (2018) Potential of restoration of gravel-sand pits for bats. *Ecological Engineering* 110: 137-145.
- Kim DH, Newton WE, Lingle GR, and Chavez-Ramirez F. (2008) Influence of grazing and available moisture on breeding densities of grassland birds in the central Platte River Valley, Nebraska. *Wilson Journal of Ornithology* 120(4): 820-829.
- Kinzel PJ, Nelson JM, Parker RS, and Davis LR. (2006) Spring census of mid-continent Sandhill Cranes using aerial infrared videography. *Journal of Wildlife Management* 70(1): 70-77.
- Kirsch EM. (1996) Habitat selection and productivity of Least Terns on the lower Platte River, Nebraska. *Wildlife Monographs* 132: 1-48.
- Krapu GL, Brandt DA, Kinzel PJ, and Pearse AT. (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.
- Kondolf GM, Smeltzer M, and Kimball L. (2002) *Freshwater gravel mining and dredging issues*. White Paper. Center for Environmental Design Research, University of California, Berkeley, CA. 122 pp.
- LaGrange T. (2005) *Guide to Nebraska's wetlands and their conservation needs*. 2nd Edition. Nebraska Game and Parks Commission, Lincoln, NE. 59 pp.
- Landin MC and Soots RF. (1978) Colonial bird use of dredged material islands: a national perspective. *Proceedings of the Colonial Waterbird Group*. 1:62-72.
- Liddick TS. (2017) *2017 coordinated spring survey of mid-continent Sandhill Cranes*. Report, U.S. Fish and Wildlife Service, Spearfish, SD. 10 pp.
- Lozon JD and MacIsaac HJ. (1997) Biological invasions: are they dependent on disturbance? *Environmental Reviews* 5: 131-144.
- Lundgren SA, Geluso K, and Schoenebeck CW. (2012) Terrestrial and semi-aquatic vertebrates in diets of Largemouth Bass (*Micropterus salmoides*) in central Nebraska. *The Prairie Naturalist* 44: 105-108.
- Matter WJ and RW Mannan. (2008) *Sand and gravel pits as fish and wildlife habitat in the Southwest*. U.S. Department of the Interior, Fish and Wildlife Service. Resource Publication 171, Washington, D.C. 18 pp.
- McCarraher DB, McDonald RA, and Adrian GL. (1974) Some hydrobiological characteristics of Interstate-80 highway lakes in Nebraska. *Transactions of the Kansas Academy of Science* 77(2): 93-102.
- Meyer CK and Whiles MR. (2008) Macroinvertebrate communities in restored and natural Platte River slough wetlands. *Journal of the North American Benthological Society* 27(3): 626-639.

- Milne BS. (1974) Ecological succession and bird-life at a newly excavated gravel-pit. *Bird Study* 21(4): 263-278.
- Mollema PN, Antonellini M, Dinelli E, Greggio N, Stuyfzand PJ. (2015) The influence of flow-through saline gravel pit lakes on the hydrologic budget and hydrochemistry of a Mediterranean drainage basin. *Limnology and Oceanography* 60: 2009-2025.
- Moser MT. (2014) *Microbial water quality during the northern migration of Sandhill Cranes (Grus canadensis) at the central Platte River, Nebraska*. United States Geological Survey, Fact Sheet 2014-3094, Lincoln, NE. 4 pp.
- National Research Council. (2005) *Endangered and Threatened Species of the Platte River* (Washington, DC: The National Academies Press).
- Natural Resources Conservation Service (NRCS). (2017) *Soil survey geographic database (SSURGO)*. Retrieved from the Internet 22 Sept 2017: <https://catalog.data.gov/dataset/soil-survey-geographic-ssurgo-database-for-various-soil-survey-areas-in-the-united-states>
- Neumann D, Seidenberg-Busse C, Petermeier A, Staas ST, Molls F, and Rutschke J. (1994) Gravel-pit lakes connected with the River Rhine as reserve for high productivity of plankton and young fish. *Water Sciences and Technology* 29(3): 267-271.
- Pearse AT, Krapu GL, Brandt DA, and Kinzel PJ. (2010) Changes in agriculture and abundance of Snow Geese affect carrying capacity of Sandhill Cranes in Nebraska. *Journal of Wildlife Management* 74(3): 479-488.
- Prosser IP and Roseby SJ. (1995) A chronosequence of rapid leaching of mixed podzol soil materials following sand mining. *Geoderma* 64: 297-308.
- Řehounková, K and Prach K. (2008) Spontaneous vegetation succession in gravel-sand pits: a potential for restoration. *Restoration Ecology* 16(2) 305-312.
- Santoul F, Figuerola J, and Green AJ. (2004) Importance of gravel pits for the conservation of waterbirds in the Garonne river floodplain (southwest France). *Biodiversity and Conservation* 13: 1231-1242.
- Sidle JG, Miller ED, and Currier PJ. (1989) Changing habitats in the Platte River Valley of Nebraska. *The Prairie Naturalist* 21(2): 91-104.
- Svedarsky WD and Crawford RD, eds. (1982) *Wildlife values of gravel pits: symposium proceedings*. Miscellaneous Publication 17, University of Minnesota, St. Paul, MN. 250 pp.
- Taub SH, Clark CF, Mayhew DA, and Lisiecki JB. (1974) *Suitability of Ohio interstate highway borrow pit ponds for sport fishing*. Research Bulletin 1064. Ohio Agricultural Research and Development Center. 24 pp.
- United States Census Bureau. (2018) *QuickFacts: Nebraska*. Retrieved from the Internet 10 May 2018: <https://www.census.gov/quickfacts/fact/map/NE/PST045216>
- United States Department of Agriculture [USDA]. (2012) *Acres of irrigated land, 2012*. National Agricultural Statistics Service, Map Atlases for the 2012 Census of Agriculture. Retrieved from the Internet 3 May 2018: <https://www.ers.usda.gov/webdocs/charts/62559/map.png?v=42285>
- United States Geological Survey [USGS]. (2016) 2012-2013 Minerals Yearbook Nebraska [Advance Release]. Retrieved from the Internet 10 May 2018: https://minerals.usgs.gov/minerals/pubs/state/2012_13/myb2-2012_13-ne.pdf
- Vrtiska MP and Sullivan S. (2009) Abundance and distribution of Lesser Snow and Ross's Geese in the Rainwater Basin and Central Platte River Valley of Nebraska. *Great Plains Research* 19: 147-155.
- Williams GP. (1978) *The case of the shrinking channels – the North Platte and Platte rivers in Nebraska*. U.S. Geological Survey Circular Number 781. 48 pp.
- Zhao T, Grenouillet G, Pool T, Tudesque L, and Cucherousset J. (2016) Environmental determinants of fish community structure in gravel pit lakes. *Ecology of Freshwater Fish* 25: 412-421.
- Zinkl JG, Dey N, Hyland JM, Hurt JJ, and Heddleston KL. (1977) An epornitic of avian cholera in waterfowl and common crows in Phelps County, Nebraska, in the spring, 1975. *Journal of Wildlife Diseases* 13(2): 194-198.