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ABSTRACT. □ This is an exploration of my personal journey from childhood to the present and how the many threads of personal discovery and meaning, family, natural, tribal and national history have been braided together over time - and how all of that led me to a career making documentary films about our region and eventually to co-found Platte Basin Timelapse which seeks to understand and reveal the essence and issues in the Platte Basin Watershed seen over time.

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## CONSERVATION NEEDS AND KNOWLEDGE GAPS IN THE CENTRAL PLATTE RIVER VALLEY ECOSYSTEM: RESULTS FROM AN INTERACTIVE STAKEHOLDER WORKSHOP

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ABSTRACT. □ The Central Platte River Valley (CPRV) is a biologically unique and important ecosystem, which supports four federally threatened and endangered species, as well as habitat for several species of regional concern. However, the Platte River has been highly augmented through the appropriation of flows for human use and infrastructure projects to manage water. Concerted efforts have been made to preserve the CPRV ecosystem since the mid-1970s. Today the CPRV continues to face a number of threats including industrial and suburban development, continued appropriation of river flows, conversion of wet meadows and tallgrass prairies to agricultural fields, and invasive species. The Platte River Basin Ecosystem Symposium (PRBES) was held yearly and later biennially between 1990 and 2003, with the goal of providing conservation organizations, researchers, and government agencies an opportunity to stay informed regarding ongoing research in the Platte River Basin and advance shared objectives for future research and management. The sixth and later the eighth PRBES, in 1995 and 1997 respectively, included participatory research needs forums. We sought to examine the current knowledge gaps in our understanding as well as the current conservation needs of the CPRV ecosystem 23 years after the original research needs forum. We conducted an interactive workshop that followed an iterative process of brainstorming, explanation, and democratic prioritization, to define and rank practical conservation and research needs in the CPRV. Workshop results ranked *habitat restoration, outreach and education, in-stream flow protection, invasive species control, and habitat protection* as top conservation needs and *human dimensions and economics, invasive species management and control, restoration research, water research, and prairie-meadow ecology* as top knowledge gaps to address. Several broader themes ran throughout the workshop, particularly the need to conduct long-term research, to coordinate more closely with partners in conservation and management efforts, and to communicate and engage with the broader community. Our workshop results demonstrate great progress in answering some research questions, and very little progress in others since the research needs forums of the mid to late-1990s.

### INTRODUCTION

The Central Platte River Valley (CPRV) is an important landscape both biologically and agriculturally, supporting one of the most productive agricultural areas in the region (Dappen et al. 2008, Thormodsgard 2009), as well as high endemic

biological diversity (Springer 1981, Hay and Lingle 1981, Lingle and Hay 1982, Nagel and Kolstad 1987, Davis 2005, LaGrange et al. 2005, Riggins et al. 2009, Geluso and Harner 2013, Caven et al. 2017). The CPRV is home to four species listed as threatened or endangered under the Endangered Species Act including the Whooping Crane (*Grus americana*), the Pallid Sturgeon (*Scaphirhynchus albus*), the Piping Plover (*Charadrius melodus*), and the Interior Least Tern (*Sternula antillarum athalassos*) (National Research Council 2005, Smith 2011), as well as 11 species listed as “tier-1 at-risk” by the state of Nebraska (Schneider et al. 2011). Furthermore, under the Endangered Species Act, most of the CPRV is listed as “critical habitat” for the Whooping Crane (USFWS 1978). However, this biologically important landscape faces significant development pressures that threaten its ecological integrity, including sand and gravel extraction, water diversion, invasive species encroachment, suburban expansion, and the continued conversion of tallgrass prairies and wet meadows to agricultural fields (Sidle et al. 1989, Eisel and Aiken 1997, Birgé et al. 2018, Pauley et al. 2018, Caven et al. *in press*). Several conservation organizations are dedicated to maintaining and improving habitat for species of concern in the CPRV, include Audubon’s Rowe Sanctuary, the Nature Conservancy, the Platte River Recovery Implementation Program, the Crane Trust, and others. These conservation organizations work closely with government agencies, the University of Nebraska system, and regional water users including the Central Platte Natural Resources District (CPNRD), the U.S. Fish and Wildlife Service (USFWS), the Nebraska Game and Parks Commission (NGPC), and others.

Identifying stakeholders is an iterative process, meaning that as an investigation deepens, new interested parties are discovered and should be engaged (Reed et al. 2009). Effective conservation strategies and habitat management actions depend on engaging a diverse constituency in the planning and implementation process (Schusler et al. 2003, Birgé et al. 2018). Social learning is a process that takes place when stakeholders communicate openly to build shared understanding, which can help create common goals and enhance cooperation (Schusler et al. 2003). This process requires a true engagement of ideas, including constructive conflict that engages disparate perspectives (Schusler et al. 2003, Bentley Brymer et al. 2018). Social learning is an essential component of collaborative resource management and is fostered by open dialogue, sustained engagement, democratic processes, inclusive participation, and constructive debate (Schusler et al. 2003). Because collaborative planning processes can be hindered by power disparities between and restrictive organizational cultures of stakeholders, planning methods that focus on *process*, for example cooperatively defining the problems, may be most effective (Selin and Chevez 1995).

The sixth and eighth Platte River Basin Ecosystem Symposia (PRBES), held in 1995 and 1997 respectively, included “research needs” forums, which provided interactive opportunities for scientists and land managers to define research priorities for the CPRV ecosystem (Eckert and Franti 1995, Herpel 1997). The ninth PRBES, held in 1998, included a qualitative analysis of stakeholder’s statements regarding resource management (Allen 1998). The 1995 research needs forum included small working group sessions, a panel discussion, and two surveys (at the start and end of the symposium) focused on determining and ranking research priorities (Eckert and Franti 1995). The 1997 research needs forum was composed of stakeholder interviews conducted in 1996 and 1997 (Herpel 1997). Results from the 1995 “research needs survey” determined aquatic habitats, flow quantity requirements, wet meadows, and riparian habitats were topic areas in need of further research in the CPRV (Eckert and Franti 1995). Each of these topic areas was further broken down by small working groups. For instance, the top research theme for “flow quantity requirements” was: “[What are the]...flow requirements to restore the desired ecosystem including threatened and endangered species?” (Eckert and Franti 1995). For the 2018 PRBES, we followed the general approach for a science-based workshop outlined by NC TraCS (2018) to determining research and land management priorities in the CPRV 23 years after the initial research needs forum was held in 1995. The interactive workshop included a diverse group of stakeholders comprised of scientists, land managers, conservationists, and interested members of the general public. The workshop process was facilitated as an open and democratic dialogue.

## METHODS

The interactive workshop was an iterative process of brainstorming, explanation, and democratic prioritization (NC TraCS 2018) focused on two basic questions regarding conservation needs and knowledge gaps in the Central Platte River

Valley. The first session addressed the question, “given what we currently know regarding the Central Platte River Valley, what are the actions we could take broadly as a conservation community to make tangible improvements to its ecological health?” The second session focused on addressing research gaps (areas not yet researched thoroughly) and knowledge gaps (holes within established areas of research) regarding the Platte River Basin ecosystem. Namely, “what are the most pressing applied research questions that need to be addressed to improve the effectiveness of our conservation efforts?” The results of this workshop are intended to serve as a roadmap, helping our conservation community prioritize and collaborate regarding conservation actions and research plans looking toward the future.

Each session began by posing one of the major workshop questions: i) *What are the most important conservation needs to address given what we know?* ii) *What are the knowledge gaps we most need to address to improve our conservation practices?* In each session workshop participants were split into 5 groups of about 5 people, and were encouraged to separate from regular coworkers and collaborators as the workshop was designed to increase the intermixing of ideas. For each session, groups independently compiled a list of responses to the session’s main question, resulting in five separate lists of topics. Following the input of participants, these items were integrated into a workable number of topics (10 -12) on a single white-board. Each participant was then given two votes to prioritize the topics they found most important to address by show of hands. Votes were tallied in real-time and the top five topics were selected for redistribution among the groups. Each group was randomly assigned one priority topic to further brainstorm on and dissect into a list of 6-12 focused themes, or if necessary, first subtopics and then respective themes. The resulting theme lists for each of the five priority topics were displayed on easel pads for all participants. Each group took turns explaining, editing, and iteratively updating the focused themes based on input from all workshop participants. Participants then voted on the clarified and updated themes, with each allowed two votes per priority topic or subtopic, to further define conservation and research priorities within respective sessions.

The workshop included 26 participants for a total of 52 potential total votes per topic, although not every participant voted on every topic. Participants represented several stakeholder organizations involved in the management of the CPRV ecosystem including the Crane Trust, Audubon Rowe Sanctuary, the US Fish and Wildlife Service, the US Geological Survey, the Rainwater Basin Joint Venture, the Platte River Recover Implementation Program, the Platte Basin Timelapse Project, the International Crane Foundation, the Nebraska Game and Parks Commission, Nebraska Public Power District, Central Nebraska Public Power and Irrigation District, Ducks Unlimited, the University of Nebraska-Lincoln, the University of Nebraska-Kearney, the University of Wyoming, and more. We summarized the results from each session regarding “conservation needs” and “knowledge gaps” in two large tables below, including both the tallied votes and the percentage of votes per theme for research topic (Tables 1, 2). The themes that received a significant amount of vote, defined here as more than 10% of the vote and one of the top four themes, were described in further detail in-text. We further explained key themes using quotes from workshop participants.

## RESULTS

### *SESSION 1: CONSERVATION NEEDS IN THE CPRV*

Given our current knowledge of the ecosystem and the threats facing it, the most important conservation needs to address in the CPRV were deemed to be: i) habitat restoration; ii) outreach and education; iii) in-stream flow protection; iv) invasive species control; and, v) habitat protection (Table 1).

Top themes to address regarding habitat restoration were to improve the connectivity of restoration efforts (25.0%), develop a strategic restoration plan (13.6%), incentivize private restoration (13.6%), and increase wet meadow restoration efforts (13.6%; Table 1). A workshop participant summed up the need for a cooperative restoration plan to improve the connectivity of restoration efforts as follows: “The idea behind a strategic plan is that we have all these habitats we want to restore, how do we prioritize them, how do we go about doing that? We have one entity working on cutting their own trees on their own property; what if we have 3 or 4 entities to attack [adjacent areas] together. We could get a lot of work

done like that. I think that's part of the strategic plan, picking your battles, what do you really need to restore first to connect areas [of quality habitat]."

Top themes regarding outreach and education were as follows: educating the general public (informal education, media) to increase support for conservation efforts (31.1%), improve university student and early career professional opportunities (funded internships) to remove bottlenecks in the university to professional pipeline (28.9%), and increasing youth engagement (outdoor classrooms, kid-centered media) (17.8%; Table 1). A participant artfully summed up the need for environmental outreach and education in the CPRV: "I think there's a real hunger out there today, and there's an entire generation of young people that are coming up and dealing with environmental issues every time they wake up in the morning. You're going to have people that have never cared about this river and these habitats because they just don't see it in their lives. But the vast majority of people have an opportunity to care, just simply open the door, shine the light. I'm seeing it throughout the entire Great Plains of North America; there is a disconnect between science and the public. It's nobody's fault, but there's great opportunity right now to build that bridge. We talked about all those tools of restoration on the land yesterday; there are lots of tools to tell stories today too, and it doesn't have to be perfect, it doesn't have to be Disney, we don't have to use technology that are delegated to NASA or Hollywood, it just has to be authentic, it has to be true."

Top priority themes regarding in-stream flow protection were as follows: revisit legal framework for in-stream flows (31.8%), conserve groundwater (27.3%), and protect natural peak flows (22.7%; Table 1). There was widespread recognition among workshop participants that their top three priority themes were highly connected. The workshop discussion regarding in-stream flows focused on refining the legal framework protecting them to allow for more flexibility and therefore improved water management in the CPRV. A participant noted, "In states where there are in-stream flow protections that allow for flexible water management it is easier to get water back into streams. For example, in Colorado, a bunch of wealthy people with hobby ranches in the Aspen corridor had great priority water rights, and no framework for transferring them to streams. If they did, they would lose their priority. They developed a framework that just allowed for the temporary transfer of water rights to the streams, so the stream didn't go dry and unprotected. You cannot do that in this state." Participants also agreed that a major challenge to securing protections for in-stream flows in a semiarid landscape dominated by industrial agriculture is the fierce competition for water resources. As one participant noted, "Any time a drop of water becomes available, there are 7 hands reaching for it."

Top priority themes regarding invasive species control included: research and monitoring of treatment responses (27.9%), secure new funding sources (23.3%), increase collaboration on priority exotic species (18.6%), and increased documentation of management actions (14.0%; Table 1). Workshop discussions focused on the need to both better document invasive species control efforts and continue long-term study of the response of invasive species and ecosystems to various treatments. The invasive species seen as most important to control to preserve the ecological integrity of the CPRV were Common Reed (*Phragmites australis*; 42.9%), Eastern Redcedar (*Juniperus virginiana*; 26.2%), Russian Olive (*Elaeagnus angustifolia*; 11.9%), Canada Thistle (*Cirsium arvense*; 7.1%), and Purple Loosestrife (*Lythrum salicaria*; 7.1%).

Top themes regarding habitat protection included: protect corridors and complexes of quality habitat (riverine, grassland) (31.0%), educate landowners on easement options (21.4%), and secure funds through partnerships (21.4%) (Table 1). Participants agreed that habitat protection should focus on protecting larger expanses of and corridors between quality habitats important to the function of the Platte River ecosystem and species of concern, including wet meadows and wide river channels. Participants also agreed that a cooperative plan would help specify priority areas and appropriate methods (easements, acquisition, etc.) for cooperative efforts to protect habitat. A nuanced conversation developed regarding conservation easement provisions, namely whether management clauses could be effectively added to agreements with private landowners, or whether properties that need significant management and restoration should be targeted for acquisition. A participant summarized this conversation well: "It's great if we have an easement on a native prairie, but, what good is it doing if we aren't helping that landowner manage their property? We do that on some [properties], but it's



up to the landowner to allow that. In terms of what you would want to have in an easement; you've got a roosting site with a meadow, you obviously don't want development. No-build easements can be fine for certain areas, but if you're talking about actual habitat, you need to have an active management component in the easement."

**TABLE 1.** Topics and subthemes outlining conservation needs given current scientific knowledge in the Central Platte River Valley, Nebraska, developed during session one of the interactive workshop held at the *Thirteenth Platte River Basin Ecosystem Symposium* on 6 June 2018 in Wood River, Nebraska. Each participant was given two votes to prioritize conservation needs topics and subthemes based on the importance of addressing them to improving and maintaining the ecological health of the CPRV.

<b>CONSERVATION NEEDS</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Habitat restoration</i>	8	18.2
<i>Outreach and education</i>	8	18.2
<i>In-stream flow protection</i>	6	13.6
<i>Invasive species control</i>	6	13.6
<i>Habitat protection</i>	6	13.6
<i>Applied research</i>	4	9.1
<i>Secure funding</i>	3	6.8
<i>Improve partnerships and cooperation</i>	2	4.5
<i>Protect native species</i>	1	2.3
<i>Improve water quality</i>	0	0.0
<b>Totals</b>	<b>44</b>	<b>100.0</b>
<b>HABITAT RESTORATION</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Improve the connectivity of restoration efforts</i>	11	25.0
<i>Develop a strategic restoration plan</i>	6	13.6
<i>Incentivize private restoration</i>	6	13.6
<i>Wet meadow restoration</i>	6	13.6
<i>Restoration funding</i>	5	11.4
<i>Create habitat buffers (around valuable habitats)</i>	5	11.4
<i>Backwater slough restoration</i>	2	4.5
<i>Facilitate partnerships for restoration</i>	2	4.5
<i>In-channel nesting island habitat restoration (for Least Terns, Piping Plovers)</i>	1	2.3
<i>Grassland restoration (focused on birds, pollinators, plants)</i>	0	0.0
<i>Riverine roosting habitat (for crane species)</i>	0	0.0
<b>Totals</b>	<b>44</b>	<b>100.0</b>
<b>OUTREACH AND EDUCATION</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Educating the general public (informal, media)</i>	14	31.1
<i>University student and early career professional opportunities (funded internships)</i>	13	28.9
<i>Youth engagement (outdoor classrooms, kid-centered media)</i>	8	17.8
<i>Landowners engagement (developing common goals)</i>	4	8.9
<i>Leverage partnerships (cross-promote, etc.)</i>	4	8.9
<i>Continuing education (adult formal programs, teacher training, master naturalists, etc.)</i>	2	4.4
<i>Encourage ecotourism</i>	0	0.0
<b>Totals</b>	<b>45</b>	<b>100.0</b>
<b>IN-STREAM FLOW PROTECTION</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Revisit legal framework for in-stream flows</i>	14	31.8
<i>Conserve groundwater</i>	12	27.3
<i>Protect natural peak flows</i>	10	22.7
<i>Minimal seasonal flows</i>	4	9.1
<i>Improve water management</i>	4	9.1
<i>Secure in-stream flows for recreation</i>	0	0.0

<i>Totals</i>	44	100.0
<b>INVASIVE SPECIES CONTROL</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Research and monitoring of treatment responses</i>	12.0	27.9
<i>Secure new funding sources</i>	10.0	23.3
<i>Increase collaboration on priority exotic species</i>	8.0	18.6
<i>Increased documentation of management actions</i>	6.0	14.0
<i>Improve public education regarding invasive species</i>	3.0	7.0
<i>Prioritize species to target</i>	2.0	4.7
<i>Reseed treatment areas (off-channel)</i>	2.0	4.7
<i>Equipment access</i>	0.0	0.0
<i>Totals</i>	43.0	100.0
<b>INVASIVE SPECIES IMPORTANT TO CONTROL</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Common Reed (Phragmites australis)</i>	18	42.9
<i>Eastern Redcedar (Juniperus virginiana)</i>	11	26.2
<i>Russian Olive (Elaeagnus angustifolia)</i>	5	11.9
<i>Canada Thistle (Cirsium arvense)</i>	3	7.1
<i>Purple Loosestrife (Lythrum salicaria)</i>	3	7.1
<i>Reed Canarygrass (Phalaris arundinacea)</i>	1	2.4
<i>Saltcedar (Tamarix ramosissima)</i>	1	2.4
<i>Smooth Brome (Bromus inermis)</i>	0	0.0
<i>American Bullfrog (Lithobates catesbeianus)</i>	0	0.0
<i>Silver Carp (Hypophthalmichthys molitrix)</i>	0	0.0
<i>Narrow-leaf Cattail (Typha angustifolia)</i>	0	0.0
<i>Leafy Spurge (Euphorbia esula)</i>	0	0.0
<i>Western Mosquitofish (Gambusia affinis)</i>	0	0.0
<i>Yellow Flag Iris (Iris pseudacorus)</i>	0	0.0
<i>Totals</i>	42	100.0
<b>HABITAT PROTECTION</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Protect corridors and complexes of quality habitat (riverine, grassland)</i>	13	31.0
<i>Educate landowners on easement options</i>	9	21.4
<i>Secure funds through partnerships</i>	9	21.4
<i>Account for future conservation needs in protection plans</i>	3	7.1
<i>Create an integrated land protection/acquisition plan</i>	3	7.1
<i>Whole channel protection for quality habitats (both sides of river)</i>	3	7.1
<i>Further develop easement options and language</i>	2	4.8
<i>Develop tools/models to identify key areas for conservation</i>	0	0.0
<i>Improve relations with adjacent landowners</i>	0	0.0
<i>Totals</i>	42	100.0

#### SESSION 2: KNOWLEDGE GAPS FOR THE CPRV

The most important knowledge gaps to address in our understanding of the CPRV ecosystem were deemed to be: i) human dimensions and economics; ii) invasive species management and control; iii) restoration research; iv) water research; and, v) prairie-meadow ecology (Table 2).

Top research themes to address regarding human dimensions and economics were: environmental values (regional opinions regarding conservation) (30.0%), evaluate the effectiveness of conservation communication (messaging efforts, etc.) (22.0%), and approaches to making the river more accessible (22.0%; Table 2). These research themes centered on conservation organizations gaining a better understanding of their neighbors and communities. For instance, what

challenges do farmers and ranchers face during the spring Sandhill Crane migration when ecotourism is high? A workshop participant summarizes this succinctly: "It is very important to understand the tension between a lot of the farmers and conservation people, as tourists stop their cars in the road and inconvenience farmers and other locals. The Sandhill Cranes are absolutely depending on the farmer's agricultural fields and the farmers are not getting much benefit from the tourism. How can we bring landowners into the economic stream?" Participants agreed that a comprehensive evaluation of farmers' and ranchers' opinions regarding conservation efforts in CPRV could be a valuable first step.

Top research themes to address regarding invasive species management and control were: best management strategies to prevent invasion (28.9%), a spatial assessment of Russian Olive and Eastern Redcedar cover (22.2%), and an assessment of biological control options (13.3%; Table 2). Workshop participants agreed that assessing the spatial distribution of the most problematic invasive species and further clarifying management strategies to control them were top research priorities. However, participants' opinions varied widely regarding the potential use of biological controls to achieve their goals and related research: "When we identify potential biological controls for some of these species ... [how can we effectively] identify unintentional consequences [of their use]? If something is utilized in Texas for a species, do we want to bring that biological control into this area?" However, key arguments for biological controls and related research were also made: "I think looking at potential biological controls instead of exclusively relying on chemicals to treat some of these invasive species might be something worth looking into."

Top research priorities to address regarding restoration research were: to summarize lessons learned from restoration projects in the CPRV (37.0%), Prairie: Determining best management practice to promote natives and control exotics (23.9%), and Woodland: Determine species benefits from woodland habitat (15.2%; Table 2). Workshop participants agreed that evaluating the effectiveness of prairie and wetland restoration techniques in both short and long-term scenarios should be a key research priority as we have very little data on how restoration efforts have fared, especially in the absence of long-term management. Research focused on the effectiveness of management techniques to control for and/or manage against invasive species in restored prairies was of particular interest. A participant asked: "We all know that [in the early stages of a prairie restoration], especially when starting from a cornfield, tilling it and then planting it, right away you're going to have a big invasive problem. Is there a way to mitigate that?" An interesting discussion also emerged regarding prairie restoration in areas dominated by closed canopy riparian forest that largely developed within the last 80 years in response to fire suppression and flow reductions in the CPRV (Currier 1982). Participants thought this area deserved further research, and one participant noted a dilemma: "Existing cottonwood gallery forests along the [Platte] river have a tremendous value for neotropical migrants.... How can you manage cottonwood gallery forest habitat in concert with crane management, which needs a wide sweep of open countryside, particularly along the river. You can maintain those gallery forests for neotropicals, or you can remove all the forest because it's a good thing for cranes. There's going to be some cost to one species to benefit another."

The topic of water research was broken up into three subtopics including water quality, physical hydrology, and riverine ecology. Top research priorities regarding water quality were: human and wildlife health (pathogens) (27.3%), downstream effects of pollution (fate and transport of particular pollutants) (21.2%), integrate water quality research with other disciplines (i.e. - as ecological indicators) (15.2%), and interactions between chemicals as well as unintended effects of chemicals (12.1%; Table 2). Top research priorities regarding physical hydrology were: the effects of climate change on physical hydrology (25.0%), identify unexpected ecosystem services provided by the river (20.0%), and the effects of hydrology on microhabitats and ecotones (15.0%; Table 2). Top research priorities regarding riverine ecology were: interactions among native and introduced species (fish species, plant species) (32.6%), nutrient cycling (natural vs. anthropogenic influences) (21.7%), integrate riverine ecology parameters into ecosystems monitoring programs (19.6%), and interactions between geomorphology and wildlife habitat (13.0%; Table 2). Workshop discussions regarding water research centered on questions regarding flow variation and habitat structure, land cover and water quality, and the potential impacts of climate change on water resources in the CPRV.

Top research priorities concerning prairie-meadow ecology were: the effects of particular management actions on species of interest (41.2%), determining, quantifying, and communicating ecological services to private landowners (23.5%), and hydro-connectivity between river flows and wet meadows (19.6%; Table 2). The discussion regarding prairie-meadow ecology centered on tracking the long-term responses of these ecosystems to land management actions (fire, grazing, haying, herbicide treatments, etc.) and hydrological fluctuations (groundwater depth, flooding, etc.). The conversation also focused on what metrics could be used to track the long-term health of prairie-meadow ecosystems. Ecosystem health measures identified included the presence of rare endemic species (i.e.- Regal Fritillary *Speyeria idalia*, Henslow's Sparrow *Ammodramus henslowii*), invasive exotic vascular plant species relative abundance, vascular plant and avian biodiversity (i.e.- Simpson Diversity Index) and species richness, relative abundance of quality nectar resources (i.e.- milkweeds *Asclepias* spp.), responses of wildlife communities across multiple taxa (i.e.- songbirds, butterflies, small mammals, etc.), and percent shrub and tree cover. Participants also discussed the difficulty of communicating the value of prairie habitats to private landowners.

**TABLE 2.** Topics and subthemes outlining current research and knowledge gaps in our understanding of the Central Platte River Valley ecosystem developed during session two of the interactive workshop held at the *Thirteenth Platte River Basin Ecosystem Symposium* on 6 June 2018 in Wood River, Nebraska. Each participant was given two votes to prioritize research topics and subthemes based on the importance of addressing them to improving and maintaining the ecological health of the CPRV.

<b>KNOWLEDGE GAPS (research needs)</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Human dimensions and economics</i>	14	28.0
<i>Invasive species management and control</i>	10	20.0
<i>Restoration research</i>	9	18.0
<i>Water research</i>	7	14.0
<i>Prairie-meadow ecology</i>	5	10.0
<i>Avian ecology</i>	2	4.0
<i>Climate change impacts</i>	2	4.0
<i>Wildlife ecology</i>	1	2.0
<i>Wetland ecology</i>	0	0.0
<i>Woodland ecology</i>	0	0.0
<b>Totals</b>	<b>50</b>	<b>100.0</b>
<b>HUMAN DIMENSIONS AND ECONOMICS</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Environmental values (regional opinions regarding conservation)</i>	15	30.0
<i>Evaluate the effectiveness of conservation communication (messaging efforts, etc.)</i>	11	22.0
<i>Approaches to making the river more accessible</i>	11	22.0
<i>Economics of crane season</i>	5	10.0
<i>Environmental impact assessment of regional ecotourism</i>	5	10.0
<i>Methods to integrate the river into public life (demonstrate its value to the community)</i>	3	6.0
<b>Totals</b>	<b>50</b>	<b>100.0</b>
<b>INVASIVE SPECIES MANAGEMENT AND CONTROL</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Best management strategies to prevent invasion</i>	13	28.9
<i>Spatial assessment of Russian Olive and Eastern Redcedar cover</i>	10	22.2
<i>Assessment of biological control options</i>	6	13.3
<i>Construct an invasion/expansion timeline for key invasive species in the CPRV</i>	4	8.9
<i>Herbicide impacts to water quality</i>	3	6.7
<i>Impacts of invasive species on grassland nesting birds</i>	3	6.7
<i>Impacts of Common Reed on channel morphology and sediment transport</i>	2	4.4
<i>Best chemicals for controlling specific invasive species</i>	1	2.2



<i>Fate of treated (dead) invasive plant materials</i>	1	2.2
<i>Impacts of invasive species on native plant communities</i>	1	2.2
<i>Identify external vectors by which invasive species could reach the CPRV</i>	1	2.2
<i>Saltcedar assessment and detection</i>	0	0.0
<i>Totals</i>	45	100
<b>RESTORATION RESEARCH</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Summarize lessons learned from restoration projects in the CPRV</i>	17	37.0
<i>Prairie: Determining best management practice to promote natives and control exotics</i>	11	23.9
<i>Woodland: Determine species benefits from woodland habitat</i>	7	15.2
<i>Prairie: Assess components of relict prairies missing from restoration seed mixes</i>	4	8.7
<i>Riverine: Assessment of recent slough restorations following floods</i>	3	6.5
<i>Woodland: Methods for maintaining relict cottonwood gallery forests</i>	3	6.5
<i>Woodland: Assessment of the benefits of restoring relict cottonwood gallery forests</i>	1	2.2
<i>Prairie: Optimizing seed mixes for application</i>	0	0.0
<i>Riverine: Identify decommissioned impoundments for removal</i>	0	0.0
<i>Totals</i>	46	100
<b>WATER RESEARCH</b>		
<b>WATER QUALITY</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Human and wildlife health (pathogens)</i>	9	27.3
<i>Downstream effects of pollution (fate and transport of particular pollutants)</i>	7	21.2
<i>Integrate water quality research with other disciplines (i.e.- as ecological indicators)</i>	5	15.2
<i>Interactions between and unintended effects of chemicals</i>	4	12.1
<i>Compare water quality between recharging vs. discharging water bodies</i>	3	9.1
<i>Integrate water quality parameters into ecosystems monitoring programs</i>	3	9.1
<i>Where are chemicals diluted and accumulated?</i>	2	6.1
<i>Impacts of physical pollution</i>	0	0.0
<i>Total</i>	33	100
<b>PHYSICAL HYDROLOGY</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Effects of climate change on physical hydrology</i>	10	25.0
<i>Identify unexpected ecosystem services provided by the river</i>	8	20.0
<i>Effects of hydrology on microhabitats and ecotones</i>	6	15.0
<i>Interactions between geomorphology and wildlife habitat</i>	4	10.0
<i>Groundwater dynamics in the CPRV</i>	4	10.0
<i>Effects of rare flow events (risk, perturbation)</i>	3	7.5
<i>Water quantity and supply</i>	3	7.5
<i>Integrate physical hydrology parameters into ecosystems monitoring programs</i>	2	5.0
<i>Total</i>	40	100
<b>RIVERINE ECOLOGY</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Interactions among native and introduced species (fish species, plant species)</i>	15	32.6
<i>Nutrient cycling (natural vs. anthropogenic influences)</i>	10	21.7
<i>Integrate riverine ecology parameters into ecosystems monitoring programs</i>	9	19.6
<i>Interactions between geomorphology and wildlife habitat</i>	6	13.0
<i>Dynamics in the hyporheic zone (subsurface flows)</i>	5	10.9
<i>Interactions between riverine and other ecologies</i>	1	2.2
<i>Riverine food web dynamics</i>	0	0.0
<i>Total</i>	46	100
<b>PRAIRIE-MEADOW ECOLOGY</b>	<b>VOTE</b>	<b>PERCENT</b>
<i>Effects of particular management actions on species of interest</i>	21	41.2
<i>Determining, quantifying, and communicating ecological services to private landowners</i>	12	23.5

Hydro-connectivity between river flows and wet meadows	10	19.6
Meadow-prairie restoration effects on biota	4	7.8
Influence of patch size on biodiversity, species use, and management strategies of prairies	2	3.9
Identifying suitable sites for Western Prairie Fringed Orchid ( <i>P. praeclara</i> ) reintroduction	2	3.9
Hydrologic and environmental influence on invertebrate communities	0	0.0
<i>Total</i>	51	100

## DISCUSSION

Workshop participants prioritized a wide range of *conservation needs* in the CPRV; however, unifying ideas were present that specified actions important to meeting our collective conservation goals. For instance, *habitat protection* and *habitat restoration* needs both focused on improving the connectivity between areas of quality relict habitat. Participants discussed the potential of creating a cooperative integrated land protection and restoration plan that would improve connectivity for species of concern through the construction of corridors and larger complexes of quality riverine and meadow habitat. This call for cooperation was echoed as a theme within other conservation needs topics; for instance, increasing collaboration regarding management for the most problematic invasive species. Other common themes included the need to secure new and sustainable funding sources and reaching out to our neighbors and the surrounding community to build support for our conservation efforts. Finally, conservation needs included protecting the historic structure and function of the CPRV ecosystem by conserving remaining quality habitats such as relict meadows and wide channels, protecting hydrological variability including peak flows, and preserving groundwater resources in the CPRV.

*Knowledge gaps* included a wide range of topics, but generally called for three different types of research: long-term research and monitoring, assessments summarizing ecological problems and methods for dealing with them, and research focused on or integrating human dimensions. The topics of *restoration research*, *invasive species management and control*, and *water research (physical hydrology)* provided good examples of long-term research themes. Some examples include: i) summarizing "... the lessons learned from restoration projects in the CPRV" [beginning in the late 1970s] by revisiting old restoration sites; ii) constructing "...an invasion timeline" for the most problematic species in the CPRV (i.e. - *P. australis*, *J. virginiana*, etc.); and, iii) identifying the "effects of climate change on [the] physical hydrology" of the Platte River. The topics of *invasive species management and control* and *water research (water quality)* provided good examples of "assessment" research themes, including: a "spatial assessment of Russian Olive and Eastern Redcedar cover" and an assessment of the "downstream effects of pollution (fate and transport of particular pollutants)."

Though *human dimensions* was a stand-alone research topic, other topics such as *water research (water quality)* also included human dimension research themes, such as "human and wildlife health (pathogens)" relating to the Platte River. Discussions surrounding this topic included the role of wet meadows as filters of water and the potential risks to humans from wildlife pathogens present in the Platte River, particularly in March during the peak of the Sandhill Crane migration. Human dimensions research topics focused on better understanding the environmental values of the surrounding community and how to engage that population in conservation efforts.

A common theme that emerged during both the *knowledge gaps* and *conservation needs* workshops was the need to increase collaboration amongst conservation organizations, government agencies, and the general public to improve conservation outcomes. Specific goals that emerged included the increased sharing of data as well as the increased collaboration in the planning of habitat protection, restoration, and invasive species management efforts.

Looking back to the research needs forums and stakeholder surveys conducted in the mid to late 1990s suggests that we have made significant strides in some respects, while remaining somewhat vexed by some of the largest challenges in terms of both conservation and science. To start, the integration of *human dimensions research* as well as *education and outreach* efforts in the CPRV have been reiterated as necessary priorities throughout the prior decades and again emerged

as a priority during the 2018 workshop. Eckert and Franti (1995) noted that small working groups identified “the need to incorporate humans into the ecosystem and evaluate the economic impact [of conservation efforts] on them” into our research and planning processes. Relatedly, Allen (1998) stated that “...we have not shared as much information with the public as we need to.” Finally, Herpel (1997) contended, “information exchange between stakeholders is a problem.” In some ways we have improved stakeholder communication, for example conservation organizations and government agencies are now relatively integrated and there has been ongoing efforts to deliver information to wider audiences, such as through educational documentaries (Platte Basin Timelapse Project; *Follow the Water*, Nebraska Educational Telecommunications 2018) or outreach events (Audubon’s Crane Festival). However, results from this workshop suggest we have not yet bridged the communication gap between conservation organizations and the surrounding community. Participants agreed that a focused effort on community engagement, open dialogue, and human dimensions research is needed to better understand public perspectives regarding the Platte River and related conservation efforts.

In this workshop we developed the idea of an integrated habitat protection, restoration, and management plan (this would encompass invasive species management as well). This plan would prioritize lands for protection, restoration, and management in the CPRV, as well as the methods by which to achieve these goals (conservation easements, tree thinning, controlled burning, etc.). Interestingly, Allen (1998) found that conservation stakeholders in the Platte River discussed this need twenty years ago “[a plan]...has to be a cooperative [effort]...that everyone can take part in, not just one particular group. Audubon can’t do it all; they’re doing all they can in the little bitty area they have, but that’s just a small portion of the channel. We need something that will pull people together. I think the irrigators and the environmentalist are starting to listen to one another more.” Today biologists from the Central Nebraska Public Power and Irrigation District, the Nebraska Public Power District, and the Central Platte Natural Resources District all share a seat at the table with conservation organizations including the Audubon Society and the Nature Conservancy in overseeing the Platte River Recovery Implementation Program (PRRIP; Smith 2011). However, PRRIP focuses on four key federally threatened or endangered species, and does not specifically coordinate with other conservation organizations to site restoration projects adjacent to existing tracts of quality habitat owned by other groups (Smith 2011). In short, the existence of the PRRIP is an improvement regarding collective conservation action and stakeholder engagement, but the cooperative plan idea developed during this workshop and in the late 1990s, has a broader and more comprehensive focus that transcends targeted management for endangered species. A cooperative plan would focus on conserving large tracts of land and corridors between quality meadow and riverine habitats to broadly benefit native biodiversity.

Aside from the comprehensive and cooperative conservation plan for the CPRV, a number of other parallels emerged between the 2018 workshop and themes from previous symposia’s research needs forums and stakeholder engagement efforts. Herpel (1997) listed investigating “...the potential impact of changing Nebraska’s [legal] system to allow for the leasing of water rights (willing seller/buyer) to acquire water for habitat in low years.” Our workshop identified “revisiting the legal framework regarding in-stream flow protection” as the top theme under the “in-stream flow protection” conservation needs topic. The laws in Nebraska still do not allow for the flexibility to lease water rights for habitat maintenance during low flow years, which is present in some other western states. In addition, the need to develop, provide, and communicate incentives to protect wet meadow habitats for private landowners was discussed at the 2018 workshop, as well as during the 1997 research needs forum (Herpel 1997).

Herpel (1997) included identifying “...species/habitat relationships and how species fluctuate under various conditions” as a research priority. Since then our understanding of various species-habitat relationships, particularly regarding species formally recognized as being “at-risk” by the NGPC or listed as “threatened” or “endangered” by the USFWS, has improved markedly. We have also improved our understanding of CPRV ecosystem’s biodiversity, structure, and function over the last two plus decades. Recent examples of work advancing our understanding of species-habitat relationships and ecology in the CPRV include: Sandhill Crane (Pearse et al. 2017), Whooping Crane (Farnsworth et al. 2018), Regal Fritillary (Caven et al. 2017), Platte River Caddisfly (Vivian et al. 2013), arthropod communities (Welti et al. 2017), native herpetofauna (Geluso and Harner 2013), Least Terns (Alexander et al. 2018), Piping Plovers (Baasch et al. 2017),

grassland breeding birds (Askins et al. 2007), raptors (Caven et al. 2018), and many more. We have also improved our understanding of wet meadow vegetation and hydrology (Henszey et al. 2004), restoration ecology (Meyer et al. 2010), and the links between physical hydrology and Platte River habitat (Horn et al. 2012). However, many technical questions regarding these subjects remain to be answered.

The largest technical knowledge gaps seem to remain in two specific genres: water research and long-term research. Participants in the 1995 research needs forum stated, “[the] establishment of some long-term ecological monitoring programs will be needed for effective management of the ecosystem” and also suggested creating an “ecological health index for monitoring [riverine habitat].” Similar ideas were echoed in various capacities at the 2018 PRBES, ranging from synthesizing long-term restoration outcomes to integrating riverine ecology parameters into ecosystem monitoring programs. Though many extended research efforts have taken place in the CPRV (i.e.- Kim et al. 2008), no consistent data collection effort, specifically regarding the vegetative community and associated fauna, has continued unabated since being recommended at the research needs forums in the mid-1990s. Fortunately, advances in technology, such as Geographic Information Systems (GIS), have allowed us to provide relatively coarse analyses of landscape level changes in the CPRV (Pauley et al. 2018). However, more specific goals laid out in early research needs forums, such as describing and classifying “the historical distribution and long-term successional trends in wet meadows” (Eckert and Franti 1995), have not yet been accomplished in the long-term decadal or multi-decal sense.

Though we have advanced our understanding of the physical hydrology of the Platte River ecosystem (Chen 2007), many questions regarding water research, particularly relating to water quality remain unanswered. For instance, the research needs forum in 1995 listed “determining [the] influences of anthropogenic impacts (non-point source – nutrients, pesticides) [on aquatic ecology]” as a priority. Similarly, understanding the “downstream effects of pollution (fate and transport)” was designated a top water research priority in 2018.

## CONCLUSIONS

It is evident that a multitude of organizations and collaborations have advanced our understanding of the CPRV ecosystem and progressed conservation efforts over the last 23 years. However, many persistent challenges remain. Increasing cooperation in regards to habitat protection, restoration, and invasive species control efforts could be key to improving the expanse and connectivity of quality meadow-prairie and braided river habitats in the CPRV. This effort would require a cooperatively developed plan and a working group to support initiatives and help coordinate the actions of multiple organizations. Stakeholder’s priorities suggest that conservation outcomes may benefit from cooperative engagement at every phase of the adaptive management cycle (Schusler et al. 2003, Williams 2011). For example, there is potential for organizations to work together to record data from their respective restoration projects in a common database to facilitate the long-term monitoring of such efforts. Financial and human resources may also be more efficiently deployed to meet conservation goals through increased cooperation. Our workshop results suggest that it is not only important to reach out to other professional stakeholders in the CPRV, but also to the wider community. Our continued success in conserving the CPRV may depend on improving our understanding of the human dimensions of our natural resources, improving engagement through outreach and education efforts, and providing incentives for private land owners to conserve and manage quality prairie-meadow and braided river habitats.

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