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Research

Longitudinal assessment of an integrated approach to large-scale common-pool water resource management: a case study of Nebraska's Platte River basin

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ABSTRACT. The state of Nebraska, USA employs a localized, integrated approach to managing water resources to address escalating quantity challenges. Here, we assess differences between agricultural water users' perceptions of water management in a water-stressed area of Nebraska after a first round of water management planning and perceptions of three other stakeholder groups in Nebraska immediately after a second round of water management planning. We also demonstrate the value of augmenting Ostrom's common-pool resource management design principles with locally relevant criteria to evaluate water management at regional and statewide governance scales. Data from a survey of Platte River basin agricultural producers in 2012 were combined with survey data collected in 2019 from Platte basin agricultural producers, Platte basin non-farm residents, and non-farm residents across Nebraska. There were significant increases from 2012 to 2019 in Platte basin producers' perceptions of four criteria and significant decreases in their perceptions of four other criteria. The current system continues to work relatively well, but notable exceptions endure, including a significant decrease in the number of agricultural producers who agree that there is equitable treatment of water users and trust in water management agencies. Non-farm respondents were significantly less likely than producers to agree that the current water management system is working well with regard to enforcing water-use rules.

Key Words: *common-pool resources; CPR principles; integrated water resources management; water governance*

INTRODUCTION

Common-pool resource management

Elinor Ostrom's body of work (e.g., 1990, 2009), for which she won the 2009 Nobel Prize in Economic Sciences, demonstrated that when certain conditions are met, communities are often capable of sustainably managing their common resources without privatization or centralized control. Ostrom proposed eight design principles characterizing robust institutions that have successfully managed common-pool resources such as aquifers, forests, and fisheries. These principles are: (1) clearly defined boundaries, (2) proportional equivalence between benefits and costs, (3) collective-choice arrangements, (4) monitoring, (5) graduated sanctions, (6) conflict-resolution mechanisms, (7) minimal recognition of rights to organize, and (8) nested enterprises (i.e., coordination in governance across scales; Ostrom 1990:90). Since 1990, new-institutionalist theorists have refined these principles (Agrawal 2001, Dietz et al. 2003, Cox et al. 2010, Poteete et al. 2010, Yang et al. 2013), and empirical studies have confirmed their general utility in evaluating large-scale common-pool resource management (Pagdee et al. 2006, Botto-Barrios and Saavedra-Díaz 2020), including confirming that the absence of some design principles increases the likelihood of unsuccessful common-pool resource management (Baggio et al. 2016).

However, critics have noted that the design principles' focus on institutional organizations can underestimate the importance of management processes and relationships and may fail to capture the value of developing trust, sharing knowledge, and creating a common understanding of resource issues and dynamics among resource users (Lebel et al. 2006). Ostrom's design principles also do not adequately address complex power relationships among stakeholder groups or their perceptions of the distribution of benefits within a community (Cleaver 2002, Hall et al. 2014). Common-pool resource co-management scholarship has demonstrated the critical functions of social capital, leadership, knowledge sharing, and external funding in creating sustainable and adaptable management systems (Armitage et al. 2009, Berkes 2009, Gutiérrez et al. 2011). Ostrom (2009) and other scholars have acknowledged the importance of these contextual factors, and over time, researchers have developed assessments of the programmatic characteristics that drive institutional success under diverse and, arguably, more complex, large-scale governance systems (e.g., Ostrom 2007, Cox et al. 2010, Babbitt et al. 2015) and account for specific conditions affecting resource use (e.g., Agrawal 2001, Dietz et al. 2003).

Findings in diverse contexts validate the usefulness of complementing common-pool resource design principles with locally derived evaluation criteria that include attention to social relationships and perceptions of fairness in supporting positive common-pool resource management outcomes (Syme et al. 1999, Kauneckis and Imperial 2007, Cinner et al. 2009, Gruby and Basurto 2013, Klain et al. 2014). However, this place-specific approach is challenging in large-scale ecological systems management, and more research is needed to assess how common-pool resource design principles tested and developed primarily in small-scale contexts can be applied and assessed in large-scale resource management systems (Epstein et al. 2014, Fleishman et al. 2014).

Our purpose here is two-fold. First, we provide an empirical analysis of regional water management systems to confirm the usefulness of complementing Ostrom's design principles with the

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aforementioned contextual factors. Our study provides a novel longitudinal analysis of the perceptions of common-pool resource principles across different stakeholder groups and at regional and statewide governance scales in a U.S. context. We use emic (situated) criteria and perceptions of success to evaluate common-pool resource management. The findings are relevant to institutional analysts and contribute empirical evidence for context-specific, process-related variables and practical understanding of the governance of common-pool resource systems. Second, we assess differences between agricultural water users' perceptions of water management in a water-stressed area of Nebraska, USA after a first round of water management planning (in 2012) and perceptions of three other stakeholder groups immediately after a second round of water management planning (in 2019). Agencies made efforts to improve the planning process between the two rounds. Thus, our analysis provides insight into how the changes may affect perceptions over time and may help others leading collaborative efforts.

Stakeholder groups in our study include irrigating agricultural producers, whose livelihoods are directly affected by regional water management, and non-farming municipal water-using residents. Successful groundwater governance is premised on several factors, including trust building and participation of all groups affected by water management, including agricultural stakeholders and the general public (Soma and Vatn 2014, Sixt et al. 2019). Although agricultural producers are often more directly involved in water management than non-farmers, both groups have a stake in the outcomes of management decisions that affect all water users. Research on public participation suggests that approaches to collaborative resource management that systematically represent stakeholders and the public are more likely to achieve beneficial outcomes (Reed et al. 2018). Thus, we intentionally surveyed both farm and non-farm households because understanding the perceptions of both groups and how they may differ is important in assessing the efficacy of common-pool resource management. Moreover, insight into how perceptions change through time over the course of water management planning can provide insight into the perceived effectiveness of processes that intentionally employ stakeholder participation in planning and implementation.

Here, we present a longitudinal case study of stakeholder perceptions of integrated water management in the fully- and overappropriated area of the Platte River basin of Nebraska. In addition to Ostrom's (1990) eight design principles, we employed seven additional criteria derived from stakeholder interviews (Babbitt et al. 2015): (1) leadership, (2) knowledge, (3) flexibility, (4) trust, (5) funding, (6) equity, and (7) proactive planning. Babbitt et al. (2015) provided an in-depth look at Nebraska's newly adopted, more localized and integrated approach to managing water resources through the eyes of agricultural stakeholders in the Platte basin. Grounded in Nebraska's specific legal, political, and historical context, we use their 15 criteria to analyze the results of perspectives of agricultural producers in the area (in 2012 and 2019), non-farm residents in the area (in 2019), and statewide non-farm residents (in 2019).

Our findings demonstrate the value of including locally relevant criteria and stakeholder perceptions for evaluating water management, particularly in assessing if stakeholder perceptions of management have changed after water agencies' intervention to improve engagement with stakeholders. Our study also responds to calls for more empirical research into the connections among common-pool resource governance, situational context, and the outcomes of management (Baggio et al. 2016, Cumming et al. 2020).

Water governance in Nebraska and the transition to integrated management

Nebraska is considered a state rich in both surface water and groundwater resources. However, the state faces major challenges, including increasing demands for water resources, conflicts between water users, concerns over threatened and endangered species, climate change, and interstate water allocation obligations. In 2004, the state of Nebraska adopted a localized and integrated approach to managing water resources to address these challenges. This integrated approach to water management recognizes the hydrological connection between groundwater and surface water and attempts to bridge the gap between the state's bifurcated system of water management, which regulates surface water and groundwater as separate resources.

Groundwater is regulated by Natural Resources Districts that are organized around watersheds with locally elected boards with taxing powers. They are authorized to regulate and to manage a wide range of natural resources, in addition to groundwater. Natural Resources Districts operate under the doctrine of reasonable use and correlative rights to govern access to groundwater. They are unique to Nebraska and have been touted as a national model for maintaining local control of natural resource management (Mossman 1996, Bleed and Babbitt 2015).

The Nebraska Department of Natural Resources (NDNR) regulates surface water resources in Nebraska. The state regulates surface water under the prior appropriation doctrine, a legal system that grants the most secure surface water rights to users with the most seniority, or "first in time, first in right".

In 2004, Nebraska passed LB 962 and amendments to the *Groundwater Management and Protection Act.* LB 962 instructed the NDNR to evaluate the long-term availability of hydrologically connected water supplies and make a determination as to whether major watersheds in the state are fully and overappropriated. According to the NDNR interpretation of LB 962, a basin is fully appropriated when existing uses of both surface water and hydrologically connected groundwater supplies are equal to but do not exceed the available water supplies over the long term (NDNR 2005). A basin is overappropriated when existing uses exceed the supply, and surface water flows can be expected to decline and groundwater table elevations can be expected to drop until either there is no water to use or the cost of using the water is too great to result in beneficial use (NDNR 2005). LB 962 also required the NDNR and local Natural Resources Districts in areas designated as fully or overappropriated to work together to manage the water resources to ensure long-term availability. The *Groundwater Management and Protection Act,* which lays out instructions for the integrated management planning (IMP) process, specifically states that plans "shall be developed after consultation and collaboration with irrigation districts, reclamation districts, public power and irrigation districts, mutual irrigation companies, canal companies, and municipalities that

rely on water from within the affected area" as well as "designated representatives of other stakeholders" (NDNR 2016*a:*22). The purpose of the *Act,* and ultimately, the IMP process, is to "extend ground water reservoir life to the greatest extent practicable consistent with reasonable and beneficial use of the ground water and best management practices" (NDNR 2016*a:*1).

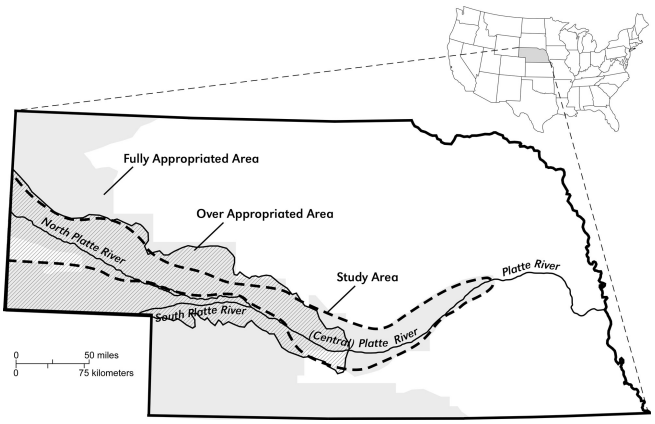
Importantly, this integrated approach legally requires consultation and collaboration between state and local agencies as well as with area stakeholders, including water users and state residents (NDNR 2016*a*). Therefore, this approach also recognizes that social connections, in particular, the active involvement of stakeholders in planning and other decision-making processes, are crucial for successful common-pool resource management (Ostrom 1990, Chapin et al. 2012, Feist et al. 2020). As a growing body of research has shown, in lieu of active stakeholder involvement in common-pool resource management, "projects can fail to meet their environmental goals because they fail to meet people's needs, their programs fail to attract participants, or they initiate change that is not sustainable and fall apart when resources are unavailable" (Prokopy and Floress 2011:83).

"Integrated Management Plans" are implemented in 10-year increments. The NDNR and Natural Resources Districts in the fully- and overappropriated portions of the basin (Fig. 1) began the first IMP process through a series of meetings with stakeholders in 2008, with plans implemented in 2009. They conducted the second round of the IMP process in late 2018 and early 2019, with plans implemented in 2019. Fundamentally, the process remains unchanged since 2008. However, between the first and the second round of the IMP process, the NDNR developed a public participation plan as part of an effort to increase stakeholder engagement (NDNR 2016*b;* Flaute et al., *unpublished presentation:* https://dnr.nebraska.gov/sites/dnr.nebraska.gov/files/doc/water-planning/presentations/2018/20180924_2018NARD_-NeDNRbasinOverview.pdf), including efforts to increase stakeholder representation beyond agricultural water users by including the general public. Additionally, Natural Resources Districts have also sought to increase participation from the general public in water management decision-making, including increasing participation from non-farm residents (Miller 2018). This step makes sense because, in practice, agricultural producers and non-farm residents alike are affected by water resource management decisions. Thus, according to the principles of stakeholder engagement and natural resource governance, all affected stakeholders should have a role in these decisions (Ostrom 2009, Lukasiewicz and Baldwin 2017). The case of legislatively mandated integrated water management in Nebraska provides an opportunity for a longitudinal evaluation of the perceived effectiveness of water management through the lens of common-pool resource design principles with local stakeholder-derived evaluation criteria.

Theoretical background

We examine water stakeholders' perceptions of the presence and strength of common-pool resource design principles at two points in time, 2012 and 2019, between which regulatory agencies increased their community engagement efforts; our objective was to understand the contextual factors and real-world application of common-pool resource governance. Stakeholder perceptions

Fig. 1. Map of the Nebraska Department of Natural Resources and Natural Resources Districts in the fully- and overappropriated portions of the basin.



are critical for informing policies that guide the implementation of design principles in practice (Bennett 2016, Running et al. 2019). However, although many studies of local-level common-pool resource management incorporate emic perspectives and locally sourced criteria, it is less common in studies of large-scale systems, where data are more frequently derived from secondary sources, and analyses use externally derived criteria for success. Our approach is informed by common-pool resource scholarship that tests the applicability of common-pool resource theory developed in small-scale settings to large-scale systems (Epstein et al. 2014, Fleishman et al. 2014) and recognizes the importance of contextual factors in understanding the conditions of successful common-pool resource management (Klain et al. 2014). By incorporating context-specific measures of success, we seek to contribute to more robust analyses of the presence and success of common-pool resource design principles in the context of large-scale social-ecological systems and processes of common-pool resource institutions and governance.

METHODS

Survey methods and analyses

The data for our study were collected from three coordinated social surveys in 2019 with questions addressing stakeholder perceptions of common-pool resources identified by Ostrom's (1990) principles and our stakeholder-determined criteria. Additionally, we included agricultural producer and irrigator data from 2012 in the fully- and overappropriated region of the Platte River basin from Babbitt et al. (2015). Numbers of participants and response rates for the four surveys are provided in Table 1. Statewide, non-farm residents' views were assessed as part of the Nebraska Annual Social Indicators Survey (NASIS), which was conceived as a vehicle both for producing current, topical information about Nebraskans (≥ 19 years old) and for monitoring change in quality of life and other social conditions in Nebraska (Bureau of Sociological Research 2019). The NASIS and 2012 producer surveys were approved by the University of Nebraska-Lincoln Institutional Review Board (IRB numbers 20160816236FB and 20120412617EX, respectively). Surveys of

Table 1. Brief comparison of the four surveys used in this study.

Year	Target population	Target area	Number of usable surveys	Response rate (%)
2012	Agricultural producers	Fully- and overappropriated portions of the Platte River basin	345	21.4
2019	Agricultural producers	Fully- and overappropriated portions of the Platte River basin	271	28.1
2019	Non-farm households	Fully- and overappropriated portions of the Platte River basin	135	16.5
2019	Non-farm households	Statewide	1131	28.0

agricultural producers and non-farm residents in 2019 were collected as part of a larger U.S. Department of Agriculture funded project studying stakeholder engagement and approved by the Penn State University Institutional Review Board (STUDY00011570).

Non-farm household survey (Nebraska Annual Social Indicators Survey)

NASIS comprised a mail survey using a postal delivery sequence-based sample of U.S. Postal Service household addresses. Addresses were purchased from Dynata, and 4800 cases were provided. These addresses were drawn from throughout Nebraska with equal probability of selection. Known vacant addresses were excluded. Data were collected between 17 July and 25 September 2019. Each survey packet contained a cover letter, a paper survey booklet, a $1 USD incentive, and one large and one small postage-paid return envelope. The survey contained 106 questions in 12 pages. A reminder postcard was sent to all non-responders approximately one week after the initial mailing. In addition to the reminder postcard, a second survey packet was sent to all remaining non-responders approximately one month after the initial mailing.

A total of 1227 adults returned the NASIS 2019 mail survey. The initial response rate of 25.6% was calculated using the American Association for Public Opinion Research's standard definition for "response rate 2". Of the 4800 addresses sampled, 6.7% (N = 321) were determined to be ineligible (e.g., no such address, vacant), and 2.0% (N = 98) were undeliverable addresses. Thus, the final response rate was 28.0%. There were 1131 non-farm respondents. Median income level for the sample was $50,000 to < $75,000 USD, and the median education level was a two-year college degree. Both of these levels are equivalent to the median income and education levels for Nebraska. The vast majority of the sample was Caucasian (93.5%), which is slightly higher than the proportion of Caucasian people (88.1%) in Nebraska, according to the 2010 Census of Nebraska (U.S. Census Bureau 2010). The participants' age distribution was: 65.7% from the 19–54 age group, 21.0% from the 55–69 age group, and 13.3% from the ≥ 70 age group, which is equivalent to that for Nebraska (U.S. Census Bureau 2010). The sample was 49.1% male and 50.9% female, which is also equivalent to that for Nebraska (U.S. Census Bureau 2010). More information about the NASIS survey is available from the University of Nebraska-Lincoln, Bureau of Sociological Research (https://bosr.unl.edu/nasis).

2019 Platte basin agricultural producer and non-farm residents survey

The Platte Basin agricultural producer survey employed a mail survey using a sample of agricultural producers > 19 years old in the North and Central Platte portions of the Platte River basin. Address information was purchased from the sampling firm FarmMktID. "Agricultural producers" were defined as individuals who had received payments from a federal agricultural program.

In the Central Platte region, the majority of the agricultural producer sample (N = 400) was drawn from stratified proportions of agricultural producers identified within four of the ten Central Platte counties entirely or almost entirely within the Central Platte watershed: Buffalo, Dawson, Hall, and Merrick. The remaining producers (N = 100) were drawn from portions of six additional counties within the watershed (as determined by zip code).

In the North Platte region, the agricultural producer sample (N = 500) was drawn from stratified proportions of all agricultural landowners identified within four counties entirely or almost entirely within the North Platte watershed: Scotts Bluff, Banner, Garden, and Morrill. The sample was stratified across these counties to match proportions of agricultural producers in each county.

We also employed a mail survey using a sample of non-farm residents ≥ 19 years old in the Platte Basin. As with agricultural producers, non-farm resident address information was purchased from FarmMktID. "Household residents" were defined as individuals with mailing addresses in municipalities within the Platte River basin. The survey was to be completed by the "person in your household who makes most of the decisions about your home, lawn and garden." Initial samples were cross-referenced with agricultural landowner lists to ensure agricultural landowners were excluded from the residential landowners list.

In the North Platte region, the sample of household residents (N = 499) was obtained from the cities of Scottsbluff and Gering, the two largest population centers in the region. In the Central Platte region, the sample of household residents (N = 503) was drawn from eight cities (Central City, Cozad, Gibbon, Gothenburg, Grand Island, Kearney, Lexington, and Wood River) and one village (Shelton) located within the region. In both sites, the sample size was stratified across each city and village to match population size.

Each questionnaire contained a cover letter, a paper survey booklet, and one large postage-paid return envelope. The agricultural producer survey contained 26 questions in 12 pages, whereas the non-farm resident survey contained 25 questions in 12 pages.

Following Dillman et al.'s (2009) "tailored design" method, a questionnaire was mailed in a series of five waves during summer and fall 2019, with a request that the survey be completed by the household decision maker. One to two weeks prior to distribution of questionnaires, press releases providing an overview of the study were sent to and reported by local and regional media

outlets. A letter describing the forthcoming mail survey with an option to take the survey online was sent two weeks prior to the first round of mail surveys sent with return stamped envelopes. Non-respondents were mailed a reminder postcard and then a second copy of the questionnaire two and four weeks after the postcard. Finally, a letter was mailed after two more weeks to non-respondents to request their completion of the questionnaire.

A total of 271 producers returned the 2019 Platte basin agricultural producer survey, for an initial response rate of 27.1%. Of the 1001 producer addresses sampled, 0.008% (N = 8) were determined to be ineligible (e.g., deceased), and 0.03% (N = 28) were undeliverable addresses. Thus, the final response rate was 28.1%. The median education level was a two-year college degree, which is equivalent to the median education level for Nebraska, according to the 2010 Census of Nebraska (U.S. Census Bureau 2010). The average age was 63.7 years old, which is slightly higher than the average of 56.4 years old for farmers in Nebraska (USDA-NASS 2017). The sample was 87.7% male, which is slightly higher than the statewide average of 77.5% for principal producers (USDA-NASS 2017).

A total of 135 residents returned the survey of Platte basin non-farm residents, for an initial response rate of 13.5%. Of the 1002 residential addresses sampled, 0.004% (N = 6) were determined to be ineligible (e.g., deceased), and 18.0% (N = 180) were undeliverable addresses. Thus, the final response rate was 16.5%. The median education level was a four-year college degree, which is slightly higher than the median education level for Nebraska, according to the 2010 Census of Nebraska (U.S. Census Bureau 2010). The average age was 58.8 years old, which is slightly higher than the approximate average age of 50 years old for residents > 19 years old in the sampled counties in Nebraska (U.S. Census Bureau 2018). The sample was disproportionately male (59.5%; U.S. Census Bureau 2010).

2012 Platte basin agricultural producer survey

The 2012 Platte basin agricultural producer survey was conducted by Babbitt et al. (2015). Although their study targeted surface and groundwater irrigators, with few exceptions, all farms in the fully- or overappropriated portions of the Platte River have some irrigated acres. Babbitt et al.'s (2015) survey also followed the procedures recommended by Dillman et al. (2009). Of the 1615 producers mailed a survey, 345 completed the survey, for a response rate of 21.4%. A full description of the survey methods is available in Babbitt et al. (2015).

Questionnaire items

All items measuring attitudes toward Ostrom's (1990) common-pool resource management principles and stakeholder-derived water management success criteria were previously developed, pilot tested, and used by Babbitt et al. (2015). Babbitt et al. (2015) conducted 35 semistructured interviews with a diverse set of water managers and water users in the Platte River basin to gain insight into the characteristics that stakeholders felt were important in successfully managing water resources in the Platte River basin and to explore how well irrigators believe the current system is working. Interviews were recorded, transcribed verbatim, coded, and analyzed to search for emerging themes. The analysis, combined with Ostrom's (1990) eight design principles, resulted in a robust list of 15 criteria descriptive of successful water management institutions: (1) clearly defined water-use rules, (2) proportional equivalence between benefits and costs, (3) an ability to influence rules, (4) monitoring, (5) graduated sanctions and enforcement, (6) conflict resolution mechanisms, (7) local control, (8) coordinated governance, (9) leadership, (10) knowledge, (11) flexibility, (12) trust, (13) funding, (14) equity, and (15) proactive planning (Table 2). Their instrument demonstrated satisfactory validity and reliability. The 2019 data were collected as part of two large attitudinal surveys covering many additional research purposes; consequently, only one survey item for each criterion was used for the 2019 surveys (Table 2).

All three 2019 survey samples received identical items. A five-point ordinal response scale measured each respondent's rating of how well each criterion is exhibited, ranging from "strongly disagree" to "strongly agree". A value of "3" indicated neither disagree nor agree. The data from Babbitt et al. (2015) were converted from an eight-point (0–7) ordinal response scale to a five-point scale in a two-step process for comparison. First, the 0–7 scale was converted to a 1–8 scale. Second, the eight-point response scale was converted to a five-point scale using the formula: $(5 - 1)(x - 1)/(8 - 1) + 1$, where x is the participant response. One-way analysis of variance (ANOVA) was used to test for statistically significant differences between the means of the four groups' perspectives on water management success (Bailey 2008). The first step in the ANOVA was an omnibus F-test of significance between all group means, which was followed by Tukey post-hoc tests to determine which of the group means were statistically different.

RESULTS

The results that follow describe convergent and divergent perspectives among the Platte basin agricultural producers after the first IMP process (in 2012) and the second IMP process (in 2019) as well as non-farm residents in the Platte basin and non-farm residents statewide. There were significant differences in perceptions of Ostrom's eight design principles across the four groups, and significant differences in three of the seven additional criteria across the four groups (Table 3).

Clearly defined rights to water use: All four participant groups generally agreed that the boundaries around the water resource system, the community uses, and the rights to use the resource are well defined. The 2019 Nebraska statewide non-farm residents thought the rights to use water were significantly more clearly defined than did the other three groups.

Costs and benefits: Three groups indicated that benefits of using water resources outweigh the costs of developing, managing, and using the resource, whereas the Platte basin non-farm residents neither agreed nor disagreed with this statement. Producers surveyed in 2012 thought the benefits were significantly higher than did the other three groups.

Ability to influence rules: Only the statewide non-farm residents tended to agree that they have an ability to influence the water-use rules. Producers surveyed in 2012 were significantly more likely to disagree than were the other three groups that they have the ability to influence rules put in place to manage water resources. However, the producers surveyed in 2019 indicated that they have more influence than did those surveyed in 2012.

Table 2. Criteria for promoting successful water management. Criteria were judged on a five-point scale, where 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree.

Criterion	Survey item
Clearly defined rights to water use[†]	Rights to use water are well defined in Nebraska
Costs and benefits[†]	The benefits of using water resources outweigh the costs of developing, managing, and using that resource
Ability to influence management[†]	Citizens are able to influence regulations put in place to manage Nebraska's water resources
Monitoring[†]	Overall, there are adequate systems in place to monitor people's use of water
Graduated sanctions and enforcement[†]	Sufficient penalties are enforced for failing to abide by water use regulations
Conflict resolution[†]	Adequate mechanisms are in place to resolve local water conflicts
Local control[†]	Local management plays a large role in how water is managed within Nebraska
Coordinated governance and integration[†]	State and local water management activities are well integrated
Leadership[‡]	Leadership in Nebraska is excellent when it comes to making decisions about how water is managed
Knowledge[‡]	Sufficient data and information exist for state and local agencies to manage water resources successfully
Flexibility[‡]	Nebraska's water management system is flexible and able to account for local concerns and changing hydrological conditions
Trust[‡]	There is a high level of trust between water users and water management agencies in Nebraska
Funding[‡]	There is adequate funding for state and local agencies to manage water resources
Equity[‡]	All water users are treated equitably in Nebraska
Proactive planning[‡]	Water management in Nebraska is proactive

[†] One of Ostrom's (1990) eight design principles.
[‡] Characteristics derived from in-depth qualitative interviews (Babbitt et al. 2015).

Monitoring: The Platte basin non-farm residents surveyed in 2019 neither agreed nor disagreed that there are adequate systems in place to monitor people's use of water. This result was significantly different from the other three groups, who agreed that monitoring is adequate.

Graduated sanctions (enforcement): Both producer groups indicated that penalties enforced for failing to abide by water-use regulations are sufficient and depend on the seriousness and context of the offense. However, the two non-farm resident groups neither agreed nor disagreed, and this result was significantly different from that for the two producer groups.

Conflict resolution: Producers surveyed in 2012 slightly disagreed that there are adequate mechanisms in place to resolve local water conflicts. This response was significantly lower than that for both producers and statewide non-farm residents surveyed in 2019. It was not significantly different from the response of Platte basin non-farm residents surveyed in 2019, who neither agreed nor disagreed with the conflict-resolution mechanism criterion.

Local control: All four groups indicated that local management plays a large role in how water is managed in Nebraska. Producers surveyed in 2012, however, were significantly less likely to agree that local control plays a large role than were the other three groups.

Coordinated governance and nested enterprises: Producers surveyed in 2012 slightly disagreed that state and local water management activities are well integrated. This response was significantly lower than those of the three other groups, who slightly agreed that state and local management activities are well integrated.

Leadership and flexibility: All four groups tended neither to agree nor to disagree that there is excellent leadership in Nebraska when it comes to making decisions about how water is managed, and that Nebraska's water management system is flexible and able to account for local concerns and changing hydrological conditions. There were no significant differences among the groups.

Knowledge and proactive planning: A majority of all four groups generally agreed that there are sufficient data and information for state and local agencies to manage water resources successfully and that water management is proactive. There were no significant differences among the groups.

Trust: None of the groups surveyed in 2019 agreed there was a high level of trust between water users and water management agencies. Producers surveyed in 2012 neither agreed nor disagreed on trust; however, there was a significant decline in producer perceptions of trust from 2012 to 2019.

Funding: The three groups surveyed in 2019 tended neither to agree nor to disagree that there is adequate funding for state and local agencies to manage water resources. However, producers surveyed in 2012 were significantly more likely than the other groups to think that funding was adequate.

Equity: All four groups tended to disagree that all water users are treated equitably in Nebraska. However, producers surveyed in 2019 thought there is significantly less equitable treatment than did producers surveyed in 2012 and state-wide non-farm residents.

DISCUSSION

Overall, our findings demonstrate the utility of complementing Ostrom's design principles with contextual factors. Our study also confirms that analytical tools used for assessing small-scale common-pool resource contexts can be expanded and implemented for use in large-scale common-pool resource systems. Together, our findings provide a more robust evaluation of the perceived effectiveness of water management in a water-stressed river basin in the U.S. context. This result is important because, without the additional criteria derived from stakeholders, an important means by which the effectiveness of managing water resources may be overlooked.

Table 3. One-way analysis of variance results for respondent group ratings of 15 water management success criteria. Values with different lowercase letters within a column are statistically different (Tukey post-hoc comparisons at $P < 0.05$).

Principle or criterion	Platte basin producers (2012)[a]	Platte basin producers (2019)[b]	Platte basin non-farm (2019)[c]	Nebraska-wide non-farm (2019)[d]	*F* statistic
Clearly defined rights to water use	3.29[d]	3.39[d]	3.22[d]	3.62[a,b,c]	16.53*
Costs and benefits	3.76[b,c,d]	3.23[a]	3.02[a]	3.13[a]	39.08*
Ability to influence management	2.47[b,c,d]	2.72[a,d]	2.80[a,d]	3.27[a,b,c]	68.69*
Monitoring	3.31[c]	3.43[c]	3.03[a,b,d]	3.32[c]	5.63*
Graduated sanctions and enforcement	3.29[c,d]	3.32[c,d]	2.95[a,b]	3.07[a,b]	9.38*
Conflict resolution	2.90[b,d]	3.18[a]	3.02	3.13[a]	6.95*
Local control	3.12[b,c,d]	3.61[a]	3.47[a]	3.62[a]	31.16*
Coordinated governance and integration	2.86[b,c,d]	3.18[a]	3.11[a]	3.20[a]	13.27*
Leadership[†]	3.00	3.02	3.06	3.02	0.15
Knowledge[†]	3.29	3.25	3.17	3.27	0.67
Flexibility[†]	3.06	3.02	3.09	3.11	0.92
Trust[†]	2.98[b]	2.76[a]	2.93	2.91	3.23*
Funding[†]	3.43[b,c,d]	3.09[a]	2.94[a]	2.97[a]	22.50*
Equity[†]	2.93[b]	2.62[a,d]	2.70	2.80[b]	5.84*
Proactive Planning[†]	3.17	3.19	3.15	3.15	0.14

* $P < 0.05$.
[†] Local stakeholder-derived criterion.

Nevertheless, our findings show important distinctions between established measures and new contextual measures. First, there were statistically significant differences in all of Ostrom's eight principles across the four groups, but only significant differences in three of seven stakeholder-derived management criteria. Additionally, the mean scores of all four groups tended to be higher for the principles than the locally derived criteria. This result may be a consequence of more focus by the NDNR and Natural Resources Districts on Ostrom's principles than the locally derived criteria. Ostrom's principles are reflected within the Nebraska IMP process and process evaluations, whereas the other criteria are not as explicitly followed (Flaute et al. 2019, Muñoz-Arriola et al. 2021).

Moreover, there were four stakeholder-derived criteria for which there were no statistically significant differences among the four groups (leadership, knowledge, flexibility, and proactive planning). This consistency among perceptions of these four criteria may represent salience among the groups with the criteria or a lack of attention by water management agencies to these criteria in the interim between the first and second round of the IMP process. Participants neither disagreed or agreed that leadership was excellent or that the water management system was flexible. Water management agencies may want to focus more attention on these two criteria. Regardless of statistical significance, the results provide meaningful information for water management agencies.

We also identified both agricultural and non-agricultural stakeholders' perceptions about how well Ostrom's principles and locally identified contextual factors operate in practice. Specifically, the longitudinal analysis examined agricultural producers' perceptions after the first IMP process (in 2012) in the fully- and overappropriated areas of the Platte River basin and immediately after the second IMP process (in 2019). If agricultural stakeholder perceptions are taken as providing credible feedback on the IMP process and changes to the process between the two events, then identifying the differences between these groups is important because it provides insight into how IMP convenors can reassess and strengthen collaboration via the IMP framework. Our findings indicate that changes to the IMP process appear to have mixed results.

A majority of respondents in all four groups agreed that: (1) rights to use water are clearly defined, (2) local management plays a large role in how water is managed in Nebraska, (3) sufficient data and information exist for state and local agencies to manage water resources successfully, and (4) water management in Nebraska is proactive. In contrast, although it is not prudent to rely on measurements at two points in time to infer a "trend" (i.e., Firebaugh 1997), we did find significant increases from 2012 to 2019 in Platte basin producers' perceptions of four criteria: (1) ability to influence management, (2) conflict resolution, (3) local control, and (4) coordinated governance. Although perceptions of the ability to influence management increased, producers in 2019 still disagreed that it is sufficient.

There were also significant decreases from 2012 to 2019 in Platte basin producers' perceptions of four criteria: (1) costs and benefits, (2) trust, (3) funding, and (4) equity. These results may reflect an emphasis in the IMP process on consultation and communication over collaboration and co-production. Both producer groups tended to be indifferent toward two measures: that water management institutions possess good leadership and that the water management system is flexible. It appears that more involvement from those directly affected by water management decisions is needed. Efforts to be more inclusive of those directly affected by water management decisions may increase perceptions of leadership and flexibility.

There were two significant differences between Platte basin non-farm residents and Platte basin producers surveyed in 2019: producers had more positive perceptions of monitoring and graduated sanctions. Those being directly monitored and thus more likely to experience sanctions within the basin were more likely to see these criteria as sufficient. There were three significant differences between Nebraska-wide non-farm residents and Platte basin producers surveyed in 2019. Producers were more likely to

see graduated sanctions as sufficient and less likely to see clearly defined rights to water use as sufficient. Additionally, Platte basin producers surveyed in 2019 did not think they had the ability to influence management, whereas the state-wide group did.

A majority of respondents in all four groups disagreed that water users are treated equitably under the current management system. Issues remain with representation of surface and groundwater irrigators. As noted in previous research (Babbitt et al. 2015, Bleed and Babbitt 2015, Reed and Abdel-Monem 2015), feelings of inequity in the Platte basin are widespread and longstanding. The NDNR emphasizes integrated water resource management principles that include equitable participation in its IMP process. Also, the NDNR worked with the Nebraska Public Policy Center to improve stakeholder engagement, and established goals to improve information sharing and to focus on stakeholder education before the second round of the IMP deliberation process (NDNR 2016*b;* Flaute et al., *unpublished presentation*). Despite these efforts, many respondents still perceived that equitable treatment is lacking, particularly between surface water users and groundwater users. Moreover, in recent interviews with stakeholders in the North Platte basin, Muñoz-Arriola et al. (2021) found that the IMP process limits surface water providers' participation and, in cases where surface water contributes to the recovery of groundwater levels, is less than equitable in terms of water appropriation. Despite the efforts to improve information sharing, there was a significant decrease in trust between 2012 and 2019 from the perspective of producers. However, in interviews with decision makers and stakeholders involved in one mandatory IMP process and one voluntary IMP proces, Reed and Abdel-Monem (2015) determined that trust developed over time. Perhaps concerns with trust, and even equity, are more of an issue among the wider public and agricultural producers who are less directly involved in the IMP process.

A majority of respondents in three groups (producers surveyed in 2012 and 2019 and Nebraska-wide non-farm residents surveyed in 2019) agreed that the benefits received from using water resources outweigh the costs of developing and managing the resource. Only the Platte basin non-farm residents were indifferent. Producers surveyed in 2019 thought the benefits were significantly lower than did producers surveyed in 2012, indicating that the benefits to irrigators may not be as great as they might have been at the time of the first IMP process.

Agricultural producers, those that use water resources the most and thus most directly experience monitoring and enforcement firsthand, were more inclined to believe that these criteria are adequate. Platte basin producers who are more likely to bear the financial burden of managing water resources were more likely to agree that funding is adequate in both years. Although these high water-use respondents seem to feel the greatest effects of monitoring and management costs, they perceive their power to be limited: they were the least likely to agree that they have an ability to influence the rules that directly affect them.

The Platte basin, and in particular, the Central Platte region, has been dealing with elevated nitrate levels in groundwater for many decades (Exner et al. 2014, NDEE 2019). Private well owners and municipalities have had to treat or find alternative drinking water supplies. Perhaps this long-standing concern is reflected in the Platte basin non-farm residents' lower assessment of water resources monitoring and enforcing water-use rules.

Producers surveyed in 2012 were the only group who disagreed that the current management system is performing well in devising adequate conflict-resolution mechanisms to manage water and that state and local water management activities are well integrated. These results indicate that stakeholders may be perceiving some success in these two criteria from the NDNR and Natural Resources Districts' attempts to facilitate dialogue and educate stakeholders during the second round of the IMP deliberation process. However, in Muñoz-Arriola et al.'s (2021) study, some stakeholders voiced concern that conflict management under the *Groundwater Management and Protection Act* was not sufficient.

CONCLUSIONS

A principal component of the integrated approach to water management in Nebraska is consultation and collaboration with stakeholders (NDNR 2016*a*). Our study demonstrates that complementing Ostrom's design principles with stakeholder-derived contextual factors provides a more comprehensive evaluation of this core component of water management in Nebraska than Ostrom's design principles alone.

According to Ostrom's principles of common-pool resource management and the local stakeholder-derived success criteria, the process is working reasonably well. After the second round of IMP, agricultural producers and irrigators directly affected by the plans generally agreed that the principles of common-pool resource management are being satisfied except for the ability to influence how water resources are managed. Notably, there was a significant improvement in this principle from the producers between the survey completed shortly after the first IMP process and the survey completed shortly after the second IMP process. Other common-pool resource management principles that significantly increased in application or visibility were conflict resolution mechanisms, local control, and coordinated governance. Non-farm residents in the basin and statewide also generally agreed that the principles are being satisfied. Regarding the stakeholder-derived successful water management criteria, results were mixed among all groups.

Assessing differences in water users' perception of water management, our second goal, shows that both groups of producers and both non-farm groups generally agreed that sufficient data and information exists for state and local agencies to manage water resources successfully and that the system in place allows proactive planning. However, producers in the basin and both non-farm groups generally disagreed that there is adequate trust and equity for successful integrated water management, indicating that there is room for improvement in the state's IMP process. Looking across these diverse stakeholder groups (farm and non-farm) suggests that using locally derived management criteria can contribute to identifying opportunities for improving common-pool resource management at the regional scale.

Declining trust in water management by producers also presents a concern to be addressed. Still, the overall agreement across criteria suggests that water management institutions are strong and sustainable. However, it seems conceivable that if the lack of trust and equity persist, sustainable water management could be jeopardized.

Overall, our findings suggest that large-scale common-pool resource governance can be evaluated effectively using Ostrom's design principles and locally derived measures of success. Drawing lessons from analyses of small-scale common-pool resource management, we sought a stakeholder-centered approach that used context-specific criteria and data on local perceptions. We believe this approach is reflective of recognition by new-institutionalists and other commons scholars of the importance of contextual and processual factors in informing common-pool resource management (Ostrom and Cox 2010, Klain et al. 2014). However, applying frameworks for examining design principles developed in small-scale context presents challenges for large-scale systems, particularly identifying the spatial scale, actors, and social and political variables to consider. In our case, this identification was facilitated by our familiarity with the context and stakeholders and our long-term interest in Nebraska's water resource management.

We draw from research on collaborative approaches to water management to make two observations. First, we ask what can be done to improve trust and equity through the integrated management process? To address the procedural dimensions of equity (Syme et al. 1999, McDermott et al. 2013), perhaps more emphasis should be placed on collaboration than on consultation with stakeholders as means to enhance trust and perceptions of fairness in decision-making. A key challenge in any collaborative effort, especially when stakes are high and stakeholders hold competing interests, as is often the case in water management, is to provide opportunities for a spectrum of social interaction across users and managers and other stakeholders. At one end of the spectrum, we find communication and consultation, including education and information provision campaigns, where the intent is to deliver facts and technical information in a one-way fashion to inform the uninformed or to solicit input on already well-developed plans and proposals. Although providing information and soliciting feedback may be necessary, these approaches do not build trust in the absence of more equitable interactions. At the other end of the spectrum, a growing body of research suggests that trust, equity, and other desirable social outcomes, including building a sense of collective responsibility and efficacy on individual and collective levels, can be achieved through two-way or more dialogic social interactions, including deliberation and knowledge co-production, that recognize the role of relationship building (Muro and Jeffrey 2012, Djenontin and Meadow 2018, Reed et al. 2018, Cook et al. 2019). In practice, this approach means creating opportunities to move social interactions beyond consultation approaches (e.g., soliciting input from stakeholders who have reliably shared their perspectives in the past or from attendees at public meetings, where they are allowed three minutes at a microphone; Leighninger 2013). Developing strategies to include stakeholder groups that are not currently engaged could help to support greater trust and equity (Turner et al. 2016). This process would involve greater investments of time and concerted efforts to bring new stakeholders to the table, build their capacity to provide meaningful contributions, and involve such stakeholders earlier in the planning and decision-making process. Future research should investigate not only participant perceptions of such opportunities, but the degree to which expectations and resources for more deliberative approaches (i.e., those that yield power equitably to all participants and build capacity for historically underrepresented groups) have been investigated and instituted.

Second, although it may be possible to investigate new, innovative, and inclusive approaches for stakeholder involvement in the integrated management process, challenges for bolstering perceptions of inclusivity and power sharing should also be considered. For instance, from the perspective of those who have been leading collaborative efforts in Nebraska, the critique about the need for more collaboration may sound naïve or misplaced. For decades, NDNR and its partners have partnered with irrigation districts, municipalities, Natural Resources Districts, and others in their efforts to develop integrated management plans. However, providing opportunity for involvement is one aspect (e.g., Putnam 2000), but attracting willing participants and building their capacity to participate and co-produce knowledge is another (van Kerkhoff and Lebel 2015). Paradoxically, the Natural Resources District governance approach may also limit stakeholder involvement and, in particular, farmer involvement. Recent interviews with agricultural producers indicate that some producers feel that their voice is represented by other producers who play active roles on boards, commissions, and through other institutional roles, thus reducing motivation to participate and represent or protect their particular interests (Burbach et al., *unpublished manuscript*).

Future research should assess the extent to which both the existing stakeholder capacities for participation in water management and the approaches taken by state and local water management agencies serve as barriers for bolstered perceptions of trust and equity. Structural barriers should also be addressed. In particular, deliberation and knowledge co-production in water management settings requires some flexibility in the rules, in terms of a political opportunity structure for collaborative efforts to make and change those rules (Schusler et al. 2003, Pahl-Wostl 2009). The extent to which this flexibility is technically, politically, or legally possible, or whether the will exists to open rules to broader stakeholder influence, should be investigated to understand why survey respondents largely perceived trust and equity as deficient. Future research should also investigate how additional locally derived evaluation criteria work together and interact with Ostrom's design principles (Baggio et al. 2016).

Our results support the notion that, under conditions of diverse and complex large-scale water governance systems, Ostrom's principles should be augmented with additional, context-specific criteria to evaluate success for both programmatic institutions and their ongoing processes. These criteria provide valuable and robust insights about how well the institution or system is working; using these criteria also provides a more comprehensive and nuanced understanding of what is and is not working well in an iterative, continually evolving system. Moreover, stakeholder-derived success criteria ensure that measures are relevant and reflective of the community's interests. Given that trust, knowledge, and social capital are developed over time, we also recommend using longitudinal studies to assess changes in stakeholders' perceptions and investment in management operations and outcomes.

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Data Availability:

The data that support the results of this study are available on request from the corresponding author, M.E.B. The data will be available at Penn State University DataCommons at the conclusion of the project in January 2023.

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