Drought impacts and management in prairie and Sandhills state parks

Abstract

The combination of decreased water availability and increased temperatures can interfere with outdoor activities, particularly with surface water decline and the increased risk of wildfire. Drought is a longer-term climate trend, but there is a tendency toward short-term reactions only when a drought occurs. Policy mechanisms for drought, where present, are often left to managerial discretion because they are not needed every year, and lack specific indicators. Recreator choices contribute to adaptation and public lands managers also shape drought response by monitoring meteorological trends and managing resources wisely. Despite these trends, no singular recreational drought definition exists. To understand socio-environmental interactions from a management perspective, this study synthesizes interview findings to provide in-depth insight about drought monitoring, impacts, and management across a variety of ecological regions in Nebraska state parks. Collectively, the eight participating superintendents oversee more than 152 km^2 of land, approximately 287 km^2 of surface water, and more than 364 km of lakeshore. The emergent properties of drought in the recreation sector include a shortage of naturally available water needed for vegetation health and animal habitat, to support lake sports, to prevent permanent infrastructure damage, and maintain visitor volumes for economic stability. The study concludes with recommendations for increasing drought resilience within the sector. *(206 words)*

Management implications:

- Drought affects the outdoor recreation sector in a variety of ways, including aesthetic effects on the landscape, species habitat, and availability of water for lake- and river-based recreation.
- Management actions to address drought in park spaces need not be costly or elaborate, and can operate in tandem with existing governing statutes. They can also be carried out under the authority of a variety of agencies and organizations with jurisdiction over land and water resources, as recreational use crosses agency mission areas.
- Drought indicators including the U.S. Drought Monitor, or Percent of Normal rainfall distribution, would serve as readily available measures of dryness to incorporate into a park management plan, allowing managers and staff to know when particular actions may be needed. *(128 words)*

Manuscript keywords: outdoor recreation, drought, water availability, public lands, state parks, natural hazard planning *(7,727 words)*

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1. Introduction: Outdoor recreation and drought

Climate studies show that drought has been a recurring feature in a variety of locations within the state of Nebraska (Tadesse et al., 2004). Cascading impacts are felt beyond the agricultural sector into recreation and tourism (Wilhite, 2011). Drought affects outdoor activities in a number of ways due, for example, to reduced snowpack or river flows (Thomas et al., 2013). Many of the impacts to the sector are a result of ecological damage as reduced stream and lake levels have detrimental effects on vegetation and wildlife (Crausbay et al., 2017). Water availability is critical for maintaining views, green hillsides, lake levels, and plants and animals in thriving ecosystems (Wilhite et al., 2007). As such, state agencies consider human health, wellbeing, and recreation in water allocation and planning processes (Young and Loomis, 2014).

Even though water loss can have devastating effects for the sector, much remains unknown about how drought affects public recreational lands and how these impacts are managed in Nebraska. In other states, the price of water can increase during a drought because of agricultural, industrial, and municipal demands (Mount et al. 2015). During droughts, restaurants may initially enact water-saving measures to avoid passing costs on to customers while golf course operators use additional water and fertilizers to maintain their facilities (Curtis et al., 2011).[1] Tourism declines contribute to the economic losses during drought years, and these economic pressures manifest in unlikely ways. A series of dry days may bring sunny conditions that initially encourage outdoor activity (Becken 2010). However, when dry days accumulate, economic losses can occur. For example, seasonal flow reductions of 100 cubic feet per second on the Niobrara River could amount to $16.4 million in losses over a decade (Shultz, 2009).

[1] In a tourism workshop with approximately 100 scientists, academics, public policy officials, nonprofit leaders, and business owners discussed the impact of weather and climate, naming a few of the drought-specific impacts.

59 As Nebraska has experienced two extended periods of "exceptional drought" status in the
60 last 18 years (United States Drought Monitor, 2018), opportunities exist to learn more about how
61 state parks have been impacted and managed in the recent past. This study examines the
62 following questions: how does drought impact state-owned parks and what are superintendents
63 doing to manage for these effects? The objective is to assist the sector to reduce vulnerability
64 during drought.
65 Assessing the economic benefits from outdoor recreation is a step toward integrating
66 recreational water needs with water planning. As the accounting for outdoor recreational tourism
67 becomes more accurate and the sector becomes more lucrative, some claim that purchasing water
68 for recreational supply through environmental and non-consumptive flows is on par with the cost
69 and benefits related to marginal cropland irrigation (Loomis et al., 2003). National estimates
70 suggest that the sector accounts for $887 billion per year and creates 7.6 million jobs (Outdoor
71 Industry Association, 2017). In Nebraska, the outdoor recreation economy generates 49,000 jobs,
72 $5 billion in consumer spending, $1.6 billion in wages and salaries, and $318 million in state and
73 local tax revenues (Outdoor Industry Association, 2017).[2] In a single year, Niobrara River in-
74 stream flows generate $10.9 million in revenue through the sale of food, rental equipment and
75 lodging from floaters (Shultz, 2009).
76

[2] Annual measures of the United States' Gross Domestic Product currently include the economic activity associated with outdoor recreation. At the national level, parsing out the recreation sector's economic value will "deepen the public's understanding" and improve long-term management of public lands (Bureau of Economic Analysis, 2017). The Outdoor Recreation Jobs and Economic Impact Act of 2016 highlights the Secretaries of Agriculture and Interior's role in new annual economic reporting for the Bureau of Economic Analysis (U.S. Congress, Public Law 114-249, 2016).

77 *1.1 Multi-level governance of public lands and water resources*

78 Multiple levels of government are responsible for water regulation in Nebraska, including the
79 prominent state-based Natural Resource Districts (NRDs), which oversee surface and
80 groundwater monitoring and policies (Herpel, 1995). This fits under the contemporary model of
81 Integrated Water Resources Management (IWRM), which denotes a cross-sector, multi-
82 geographic system that brings together professional expertise around overlapping management
83 functions (Grigg, 2008). The contingent nature of drought makes it difficult for state and federal
84 managers to plan for protective activities, since they are not routinely needed each year.
85 Information-sharing networks of public and private actors can ease management difficulties
86 (Cheng and Sturtevant, 2012). These networks require a public agency champion as well as
87 political and technical cores (Agranoff, 2006). For reservoir management, scaling governance to
88 natural boundaries brings higher levels of agency participation. Newig and Fritsch (2009)
89 suggest that in the case of municipal water provision, the proposed construction of an additional
90 dam requires bringing in more agencies and sectors in a holistic way to arrive at an ecologically
91 sound decision. Within the NRD system, state park areas are under a multi-level governance
92 structure. In Nebraska, multiple state and federal agencies also manage reservoir resources.[3]

93 Similarly, stream protection is achieved through a variety of measures. Nebraska state
94 law highlights fish protection when streams are dry, granting the Nebraska Game and Parks
95 Commission the authority to relocate fish that are threatened by an emergency caused by a
96 drying up of habitat waters (Revised Statute, Section 37- 321). This authority is not linked to
97 climatological indicators, so discretion lies with managers. The NRDs acknowledge the
98 interwoven nature of ground and surface resources and use the principle of conjunctive water

[3] The Calamus Reservoir Resource Management Plan, for example, refers to multiple use and conservation objectives (wildlife, fishing, recreational boating, and crop irrigation) to be achieved under the governance of multiple coordinating agencies (Bureau of Reclamation, 2010).

99 management to guide decisions about the hydrologic budget (Central Platte NRD, 2011). In
100 addition to legal codes pertaining to species protection, energy districts influence water supply.
101 Though these functional districts' primary purpose may be agricultural surface water storage
102 oversight or energy production, these special-purpose governing districts have authority to make
103 decisions about recreational waters.

104 During drought years, surface water irrigation and ground water pumping can reduce
105 water availability for non-consumptive uses. Reservoir storage is a common back-up supply
106 source used in the United States during drought years, and Nebraska is no exception. Federal
107 agencies, including the Bureau of Reclamation, maintain reservoir storage at several locations
108 throughout the state. Additionally, the state's public power and irrigation districts manage
109 reservoir surface water storage (Nebraska Public Power District, n.d.). The Game and Parks
110 agency assesses entry fees, manages the land around reservoirs, and the sets guidelines for the
111 types of activity that are permissible on recreational lands and waters. The figure below
112 highlights the overlapping and nested authority of the Game and Parks agency (Figure 1).

113 *{Insert Figure 1 here.}*

114 These overlapping entities have an array of legal resources and planning documents to
115 respond to drought conditions. NRDs identify conditions in water-short years, which are
116 connected to a series of depletion reduction measures that include a reduction in irrigated acres
117 and additional monitoring of consumptive water use (Nebraska Department of Natural
118 Resources, 2009). However, the implementation of these plans in park spaces depends on
119 proactive management. As with many environmental challenges, often the science behind trends
120 is complex and involves multiple physical and social systems (Eakin and Luers, 2006).
121 Furthermore, solutions to these problems can vary to the degree that they are able to address the

short-term and the long-term problem dimensions. Ongoing research investigates the effect of human influence and industrial activity on climate systems, but far less is understood going in the other direction, about how climate variability affects human activity. For example, water suppliers in municipalities must decide when conservation measures are necessary, and drought can sway these decisions (Engle, 2012).

1.2 Adapting to drought

The U.S. Great Plains is only a few generations removed from droughts of epic proportion. During this time, some migrated back to cities and away from deteriorating lands, while others stuck it out hoping for better times. Plains settlers adapted their agricultural production tactics in incidental and purposeful ways in order to thrive in adverse conditions: gentle tilling, cropping rotations (Polsky and Easterling, 2001), and irrigation can reduce agricultural vulnerability when rainfall declines.

Drought adaptation practices for the recreation sector may be following a similar trajectory. Recreators are both citizens and consumers, and outdoor recreation is a rapidly evolving sector that adjusts to preferences and demands made by public and private lands users. Reservoir access initially led to growth in speed boating, while recent activities are tailored to changing water levels. Paddle boarding, packrafting, flyfishing, logrolling and other non-motorized activities have emerged, but land-based activities also continue to be important, with running as the most popular outdoor activity (Outdoor Foundation, 2017). Approximately 49% of Americans participate in outdoor activities, with 11 billion outings each year (Outdoor Foundation, 2017). Novel equipment and clothing may keep recreators comfortable in a range of conditions, but at a certain point, extreme heat and dryness may pose significant barriers.

145 Outdoor recreation is a sector driven by perceptions, and daily weather conditions can
146 have an impact on whether tourists choose to take part in popular outdoor activities. For
147 example, Perkins (2016) found that rainy or wet conditions were significant deterrents to
148 attendance at zoological parks, while daily dry conditions were associated with higher park
149 attendance. These daily weather conditions can also affect tourists past perceptions of a trip.
150 Gössling et al. (2016) found that rain is the main weather-based influence on negative memories
151 of a holiday for European tourists. These recent studies suggest that dry days may be beneficial
152 for outdoor activities.

153 A noted barrier in researching drought in the recreation sector is that managers may not
154 immediately make connections between outdoor activities and longer-term climate patterns.
155 Thomas and Wilhelmi (2012) examine tourism/recreation in Southwestern Colorado, finding that
156 stakeholders in water recreation activities such as fishing or rafting identify closely with natural
157 resource and water management but that others may be more hesitant to report their
158 observations, claiming expertise in tourism but not drought.

159

160 **2. Methods**

161 To create a baseline of understanding about drought impacts and response in Nebraska,
162 we asked park superintendents what effect drought has on parks, and how they protect outdoor
163 recreation spaces. Superintendents participated in interviews on a voluntary basis. Participants
164 were sent formal, Institutional Review Board-approved invitation letters indicating that they had
165 been specifically chosen as an expert population (Ritchie et al., 2014).

166 *2.1 Data collection*

From a list of 15 invited agency representatives, 8 (53%) responded and participated. The semi-structured interview protocol designed for a 30-minute interview was conducted by telephone[4] due to the large geographical distances involved. All participants answered the full set of questions in the intended time. The prompts were designed to determine how drought affects state-owned parks and what is being done to manage these effects. The questions were co-developed and piloted with three drought impacts and management experts. Interviewees received the questionnaire two days in advance, so that they had ample time to consider their opinions and experiences. The table below provides the list of questions, their intent and the allotted time for each (Table 1).

{Insert Table 1 here.}

A reflexive interview environment[5] deliberately fostered interaction between the interviewer and the interviewees[6] to value technical experts' knowledge and build trust (Rubin and Rubin, 2012). Semi-structured interviewing allowed participants to expand on additional observations when they felt it was relevant.[7]

2.2 Data analysis

[4] Telephone-based interviewing is a common approach for qualitative research (Christmann 2009). This setting required clear articulation of concepts and ideas, since communication was not aided by non-verbal gestures.
[5] The interviewer provided analogies in some instances to build rapport with the interviewees, based on her knowledge of park visitor trend monitoring in other places.
[6] Though the main question areas were set and unchanging, the interviewer asked follow-up clarification questions when necessary. The ultimate goal was to build a solid and deep understanding between the participant and the researcher. Since each of the interviewees holds a great deal of knowledge about the topic of park management, they were a source of current practitioner knowledge. Expert interviews are used to collect operational knowledge about management from a special segment of the population who has a detailed understanding of a topical area, and responsibility for problem-solving in an area.
[7] The researchers were aware of the risk of diversion, since the interviews are social settings that were at risk of conversational divergence and interference (Bogner and Menz, 2009). As such, this technique took some practice and refining to master. The authors refined the questions with perspectives from economic, sociological, and climatological researchers before conducting interviews, and consulted with these colleagues during the data collection phase.

183 The interviews were recorded and transcribed as verbal data. Nvivo software was used
184 for systematic content analysis and the coding procedures were documented in a project
185 codebook (see Table 2). The majority of the codes were determined *a priori,* based on
186 international drought monitoring, vulnerability, and management guidelines (Wilhite, 2014) with
187 several additional sector-specific sub-categories emergent upon initial review of the data
188 (Stemler, 2001). Two researchers discussed the patterns, themes, and relationships in the data on
189 preliminary examination of the transcripts. The interpretation of interview data was done
190 iteratively by these two coders to reflexively analyze, rather than simply repeat or report upon,
191 the understandings and perspectives of interviewees (Crang, 1997). Theoretical density was
192 assessed via the repetition of themes from one interview to the next (Glaser and Strauss, 2009).
193 Comments and reflections were recorded in memos as the two coders compared results. Table 2
194 contains the codes used, along with a brief description of each.
195 *{Insert Table 2 here.}*
196 Intercoder reliability checks generated several new subcategories of the analytical
197 schemes – particularly with regard to the visitation data collection done by superintendents and
198 the segmentation of visitors and their origin. We found that adding these categories did not
199 weaken the analytics behind the scheme, because the nodes were still substantially different from
200 one another (Campbell et al., 2013). Generally speaking, the sociological methods literature
201 suggests that at least 10% of the interviews should be coded by more than one analyst (Campbell
202 et al. 2013). We coded 12.5% of the interview data jointly for the intercoder reliability (ICR)
203 test. One author coded the remainder of interviews after completing the ICR on the calibration
204 interview.

205 Kappa values ranged from 0.4 to 1. The Cohen's Kappa measures the agreement between
206 two coders that does not occur by pure chance. In the case of total agreement, the score would be
207 1, or "perfectly reliable;" on the other hand, a Kappa value of zero implies that no more
208 agreement occurred other than what would happen by random chance (Stemler 2001). [8] The
209 codes added axially received a 0, since they were built in after the coders discussed their findings
210 in light of the first interview results. It is common for axial codes to lack agreement, as one coder
211 did not have these as an option while completing the review of the first interview data.
212 *2.3 Park study sites*
213 The eight study sites are dispersed across the state. Chadron was the state's first park, founded in
214 1921 in the Pine Ridge area in the northwestern part of the state. It is known for its bluffs and
215 buttes landscape, nearby rodeo and Fur Trade Days, and the newly popular racing (running and
216 triathlon) events. Lake McConaughy State Recreation Area is also in western Nebraska and has
217 the state's largest reservoir. Fort Robinson is a former military outpost with officer's quarters,
218 equestrian trails, and wildlife viewing. Moving east, Calamus Reservoir is known for its white
219 sand beaches, power boating, jet skiing, and hunting. Lewis and Clark is Nebraska's second-
220 largest reservoir, with speed boating, jet-skiing and sailing. Closer to Lincoln and Omaha,
221 Mahoney State Park has camping, sledding, a water park, and lodge. Lake Wanahoo and Two
222 Rivers State Recreation Area have fishing and camping, as well as trout lake and river access.
223 Figure 2 displays the location of the areas included in the study.
224 *{Insert Figure 2 here.}*
225 These areas are known for land- and water-based activities, and each has a distinct character.
226 These activities are summarized below in Table 3.

[8] The equation for the kappa score is: K= (Pa – Pc) / (1 – Pc) where Pa is the proportion of units where the raters agree, and Pc is the proportion of units expected to be agreed by chance (Stemler, 2001).

227 *{Insert Table 3 here.}*

228

229 **3. Results**

230 This section summarizes reported drought impacts and management actions, identifying
231 common themes. The first finding is that droughts are defined and monitored in a variety of
232 ways. For parks with reservoirs and streams, surface water availability is a readily visible sign of
233 change. For others, the onset of dryness was linked with dying grass and trees. Managers track
234 visit numbers, but were not certain what effect drought has on overall visitation trends, simply
235 noting that if a drought is associated with heat, water activities may be more popular. Impacts
236 varied by season, ecological cover type, and extant water resources. As such, management
237 actions also varied, ranging from safety procedures to basic facilities maintenance or adapting
238 individual campsites.

239

240 *3.1 Drought monitoring sources*

241 Superintendents use a variety of sources to obtain information about the weather and
242 seasonal climate trends. These sources range from the U.S. Drought Monitor, the National
243 Weather Service forecasts, and official communications from the Game and Parks Agency.
244 These climate-monitoring sources appear in Table 4.

245 *{Insert Table 4 here.}*

246 Beyond these sources of information, some participants relied on anecdotal knowledge about
247 weather patterns. One superintendent indicated that he got a sense of what was occurring by
248 looking out the window or being outside.

249 Observational sources include on-the-ground vegetation condition monitoring; some
250 participants assess drought conditions if grasses and trees began to suffer. If plants are green and
251 growing, a few managers seemed not to worry about drought. Another mentioned that
252 knowledge about drought would not necessarily lead to a change in operational practices and
253 procedures, noting that short-term trends were more relevant.[9]
254
255 *3.2 Measuring visitor trends*
256 Superintendents use a variety of methods to track park usage and visitation, including
257 magnetic car counters. Magnetic "loop" counters are contact sensors that can detect
258 ferromagnetic materials passing over them, including bicycles and automobiles (Hornback and
259 Eagles, 1999). These have historically consisted of electrically charged cables underneath the
260 road surface; in recent designs, pads are attached to the road surface (Ibid). Multipliers are used
261 to estimate the total number of visitors based on averages of how many arrive in each vehicle.[10]
262 Other reported methods for tracking visits include campground occupancy rates, park
263 permit sales, visitor and angler surveys, vehicle tag sales, and the number of reservations for
264 cabin stays. Participants noted that car counters were damaged during road surface maintenance
265 procedures, and in some cases were not replaced. Monitoring efforts are also complicated in
266 areas where there are large numbers of private access points. For example, there are an estimated
267 50- to 60- private properties adjacent to one of the parks. The park superintendent estimated that
268 tracking additional visits from private access points would result in more than several million

[9] This comment was stated as, " We would really only monitor our weather day-to-day, week-to-week – while those two things certainly are correlated, I wouldn't say we necessarily—If it's been an abnormally dry year and we're in a red drought condition, are we going to change the way we do our normal operations or communications? Probably not greatly." (Int 2)

[10] The multiplier for some parks was quite high, and one Superintendent reported that it was 4.25 per vehicle, reasoning that "we're out here in the Sandhills in the middle of nowhere, and people are bringing their families."

each year. However, this superintendent noted that the same methods of estimating visitation had been used for at least the past 25 years, and he felt that even if they were not completely accurate, they were consistent and could be used to analyze change over time.

Determining the effect of drought on park visitation is complicated, but several managers agreed that warm, sunny weather was associated with an increase in water sports. At a prominent reservoir park, the superintendent stated that hot and sunny conditions are beneficial for water-based recreation. Another manager also made the connection between drought and heat, saying that "with the drought, more or less the heat that goes along with the drought, so… your water, your state recreation areas with water recreation are typically a lot busier with boating and swimming."

3.3 Historical drought impacts

Droughts, as with other climate memories, can blur together across the years of a manager's experience.[11] Historically, Great Plains farmers' and ranchers' perceptions of the length of exposure to drought and flooding varied. Farmers of different crops have divergent perceptions of a drought event; individual disposition can also lead some to be more optimistic than others (Saarinen 1966). Recreation is an arguably even more subjective sector. Given this dependence on perceptions, it is remarkable that nearly all of the managers immediately recalled the major drought event of 2012. During the summer, statewide conditions were hot in addition to receiving very little rainfall. The weather station in Chadron recorded a high temperature of

[11] When asked about drought, some participants responded with memories of flooding. Prior to 2012, one senior superintendent recalled a drought in 2006-2007, and additional dry years in the late 1990s and the late 1980s. In his memory, these drought events blurred together with flooding, as he recalled,

> "Well yeah it's been a long time since the late 90s. I mean we had drought in the late '80s and then in '91 for instance we had a 500-year flood here. So you know, if I remember right then it kind of dried out in the late '90s were a little wetter, but it wasn't nothing noticeable or – we were just kind of normal, you know. Things were pretty good. Not really a drought or not really too heavy moisture either, just from what I remember of it."

107ºF on July 21, only three degrees lower than the record high.[12] Wildfire during September necessitated shutting down Chadron State Park. The superintendent reckoned that the Complex 23 fire burned 256,000 acres.[13]

At Lake McConaughy, the annual precipitation at the Kingsley Dam weather station was 8 inches for 2012. This stood out to the superintendent, and matched with the station data, which showed that 2012 was the driest year on record.[14] This was markedly different from 2010 and 2011, which were wetter years, each receiving 22 and 25 inches of rain. Though lake volume may not have notably declined, the longer-term effects from the 2012 drought at Lake McConaughy included tree mortality. The superintendent stated:

> "Now, from a long-term standpoint, what did it do to the park? We're still suffering some of the effects from that drought in 2012. We've got, you know the entire reservoir is lined with 60-, 70-year old Cottonwood trees and we still have trees that are cracking and falling over because of that severe stress that they were placed under in 2012."

Ecological conditions, for this manager, related to the soil type. He said, "you know, there was no moisture in this sandy soil at all. And it takes those trees, the big old cottonwoods, it'll take them 5 or 6 years to really, truly die."[15]

With decreased precipitation, managers noted some initial changes in the lakebed of a Sandhills Reservoir. The 2012 drought was associated with decreased water levels, changing the sand formations and patterns around the Calamus Reservoir. However, the next spring brought rains that changed the topography of the lake yet again. A recollection was that "we have an area called Buckshot Bay, and that drought that year created a sand peninsula that almost closed the bay off to boater access – but that following spring we had a lot of rain that brought that water

[12] NOAA NCEI Daily Summary data, available online: https://www.ncdc.noaa.gov/cdo-web/datasets#GHCND
[13] This represents the manager's estimated recollection.
[14] Global Summary of the Year data, available online: https://www.ncdc.noaa.gov/cdo-web/datasets/GSOY/stations/GHCND:USC00254455/detail
[15] It is noteworthy that even though 2012 was an intense drought year, visitor volume was higher than ever, topping over a million visitors.

311 up. So, it actually kind of washed that peninsula." The change-over between extremes of
312 flooding and dryness was also reported in river hydrology, as another noted that the fishing was
313 down in 2012, but perhaps more due to the flooding of the prior year, which had "flushed" fish
314 downstream in the Missouri River. Though the attribution of changes to drought were mixed
315 with observations related to flooding, there were some drought-specific impacts noted. These
316 general observations appear in Table 5 below.

317 *{Insert Table 5 here.}*

318 *3.4 Seasonal drought impacts*

319 Drought impacts varied by season. The manager of a large reservoir noted more nuanced
320 effects of fall drought on Sandhill streams, noting that if late months are drier than usual, many
321 of the small steams "just don't run," pushing hunters and anglers out of the areas. On the other
322 hand, in wetter years, later season hunters find suitable habitat for a range of activities. As one
323 interviewee put it,

324 "You know, no water in those streams, there's not going to be any waterfowl, not going
325 to be any wildlife, not going to be any trout moving up in those streams. Later in the year,
326 you know on the flip side of that if we've got a really wet year, and there's a lot of water
327 moving in there, guys will start moving into some of the backwaters, the marshes and
328 those streams."

329 In this manager's mind, drought may be incompatible with the more adventurous type of angling
330 activities that the Sandhills are known for in a wet year. These seasonal trends (listed in Table 6)
331 also brought up geographic perspectives on drought, with several managers tuned into the
332 upstream snow pack levels farther west in the North Platte basin and in the Rocky Mountain
333 region.

334 *{Insert Table 6 here.}*

Managers observed that visitors adapt to the flux of dry and wet conditions. For example, if there was less snow during the winter in a park known for cross-country skiing, then birdwatching may have become more popular.

> "Yeah, so you know, if we have a lot of snow … we'll cross country ski or we'll go snow shoeing, but then when we don't have a lot of snow … we still get people that want to come out and hike and still bird watch, and you know, still be out in nature."

This finding is consistent with the literature about recreators' ability to change their activities when water conditions do not match up with the original intent (Richardson and Loomis, 2004). However, some recreators are more susceptible to drought than others, particularly if a drought occurs in the summer. High temperatures that accompany a drought threaten health and wellbeing. Resources and equipment make a difference in comfort levels. Campers in tents are more exposed than in air-conditioned recreational vehicles (RVs). Several managers mentioned this. One said that tent campers are "baking" inside their tents. This manager said that RVs are more capable of adjusting because they are able to control their temperature and shade.

Though recreators are able to adjust to drought conditions, the ecological features of a park may suffer. For example, newly planted seedlings and grassy areas are under stress in drier conditions. Participants also recognized the resultant fire risk of dry vegetation within the park. The surrounding crop fields posed a fire threat, where dry corn and bean fields during the 2012 drought were susceptible to burning.

Winter droughts can have a range of surprising effects: at Calamus, this was the case in recent years. The superintendent mentioned,

> "Because we've experienced here, was it two winters ago, we didn't get any snow – no moisture and we were pretty dry up here. It was pretty scary up here that time of year. It was pretty warm and dry, so that put us in a fire season in the winter, which usually never happens, and that put us all the way into spring, and I'm trying to think of what year that was, I think that was in 2015, the winter of 2015, because I remember in March we had a few fires around in the area, nothing on the park, but that was in the general vicinity of the park, and I know we were in high fire/extreme danger for that winter, in May."

Fire risk is alarming, and brought about precautions. If a drought occurs during winter or spring, there may be restrictions or delays on prescribed burning activities.

Parks with large amounts of surface water storage may be less disrupted during drought years. Coldwater fish species are less detrimentally affected when they have deep enough water during increased temperatures. In a large Sandhills reservoir, "The lake is deep enough, those fish found – they found their deep spots to hang out."

There were marked differences between parks located in separate eco-regions. Parks with recreational infrastructure including buildings, pools, and aquatic features may face impacts to infrastructure. In a large park along the Missouri River with a storage reservoir and hillside cabins, prescribed burns were required to prevent large fire events. Meanwhile, a smaller-acreage park along the same river faced built infrastructure risks to pools, aquatic features, and lodging. Winter drought could affect built infrastructure like water supply pipelines to cabins. Following the 2012 drought, a manager mentioned that the lack of moisture in the ground may have allowed the frost to go deeper, and freezing pipes.

Finally, participants noted that these single-season impacts could quickly be reduced with a large precipitation event. As a Sandhills manager noted, the winter and spring of 2015 were dry, and several fires occurred in the surrounding area. However, his concerns were alleviated with large amounts of rain:

> "[the rains] changed the dynamics of the park quickly, but we were pretty worried that year of what that was going to do for the grass in the park, for the trees in the park, but when you get that 20 inches of rain in May, that makes up for no rain in the winter, no snow in the wintertime."

{Insert Figure 3 here.}

It is noteworthy that not all of the summer impacts were negative, and for a major reservoir that is located along the border of the Sandhills and the short-grass prairie, decreased lake levels

simply mean that boaters would rotate to another part of the lake. For this manager, the park is a "water-based recreation paradise:"

> "it takes a very prolonged drought to lower our water level enough to the point where we would ever have an adverse effect on park visitation. We like to say that we have park migration… because there are certain areas in the upper area of the reservoir that then might become dry, that people might migrate down to the other end of the lake but they're still out here one way or the other."

The regional ecology of sandy beaches cushions aesthetic decline: when water levels are lower, the beach area expands without exposing rocky outcroppings. Visitation seemed similarly resilient on the eastern side of the state, since the camping is limited but in high demand in the summer.

3.5 Managing in dry years: Reported practices

Superintendents reported a desire to preserve park infrastructure, equipment, and the greenspaces around public buildings. **Facilities maintenance** was the top management concern during drought. One noted that, "There's not a whole lot that we have the ability to do (about drought) funding and time management wise." Therefore, a key concern was to ensure compliance with the park management plan. Where dry conditions interfered with that plan, managers took steps to alter their practices. Having a watering plan for priority or stressed areas aided turf maintenance during drought. Near entrance stations, marinas, visitor centers, and areas that receive high traffic, it was important to keep the grass presentable to park guests. Knowing that budgetary constraints would prevent irrigation in the campsite areas, managers keep the grass longer and lengthen the time in between mowing intervals.

Other measures involve facilitating the flow of visitors and access. For parks with lakes, managers move boat docks when water levels decline.[16] During the summer, one manager

[16] This does not always coincide with drought, as some movement in lake levels is normal and expected throughout the irrigation season.

412 reported moving the docks twice per week. In other instances, when changing water levels
413 washed out peninsulas, it required dredging new canals for boaters to access areas of the lake.
414 For parks with unpaved roads, it is necessary to control dust levels, or service the tractors used
415 for road maintenance.

416 Other reported actions include watering newly-seeded areas if it is unusually dry, since
417 grass, shrubs, and trees in these areas do not have the well-established root systems to withstand
418 longer dry periods. **Ecological systems management** focused on the wellbeing of wildlife and
419 plants outside of built-up areas. Response measures included cutting down or digging up stressed
420 and dying trees. Another way to alleviate fire danger was to graze wild meadows, reducing the
421 grass fuel. Preventive and proactive planting of native forbs, bluestem grasses, and plum thickets
422 helped reduce the risk of future drought damage.

423 Variation between vegetation cover and climate correlates with differences in
424 management approaches. In Eastern Nebraska, a manager noted that the deciduous forest would
425 not be as susceptible to fire as the pine-dominated landscape of the Western side of the state.
426 However, **fire prevention** was in the top three management concerns for superintendents across
427 the state. Fire extinguishers are kept in all vehicles and buildings since fire is a major concern
428 during drought. Where necessary, signs are posted to put out cigarette butts, avoid parking on dry
429 grass, or accidentally lighting fires by driving vehicles over dry areas. Fire restrictions and
430 campfire bans are implemented when it is extremely dry. The figure below summarizes how fire
431 prevention fits with the other management actions that superintendents reported using during a
432 drought (See Figure 4).

433 *{Insert Figure 4 here.}*

Some managers reported continuing **business as usual**, with the rationale that routine operational practices were sufficient. For example, in one park, campsites were designed with mowed areas, fire rings, and waist-high grills so that fire restrictions would not be necessary. In their defense, managers highlighted that they do not have a lot of spare time to consider drought management. One superintendent emphasized this "make-do" attitude, saying, "We're a pretty bare bones operation. It pretty much is what it is." This participant felt, at minimum, a responsibility to keep park visitors safe. **Safety procedures** during drought involved educating the public about risks, by using signage. When lake levels declined large amounts, managers put signs, buoys and other markers up to prevent boaters from hitting objects in the water.

Drought conditions were linked to emergency **human resources and staffing concerns**. When drought posed a risk to structures, additional staff repaired broken frozen pipelines or fought fires. In other instances, staff directives included keeping vehicles from driving over flammable grass. Additionally, a manager mentioned that if a park were to receive an influx of visitors, it would sometimes be necessary to have more staff to deal with the additional visitors.[17]

Forest management is a recognized dimension of a drought program, as healthy forests are less likely to be stressed by water shortage, and are less of a fire risk. To maintain adequate spacing, thinning procedures create spacing between trees, effectively slowing the spread of wildfire. To achieve landscape-scale objectives, superintendents **coordinate with partner agencies** and adjacent landowners to monitor conditions and formulate plans on issues from prescribed burning to seeding areas around waterways to prevent erosion. Participants recognized that efforts are more successful when adjacent lands are under similar treatment, rather than approaching them in a patchwork fashion.

[17] Increased visits were associated with the 2012 drought conditions at Lake McConaughy.

Finally, park guests and recreators demonstrate **individual-level adaptation measures**. In hotter, dry conditions, the pool sees an uptick in visits. Horseback riding or fishing is more popular early in the day, rather than during the peak of the heat. Additionally, portable equipment allows for campsite modifications that make guests more comfortable. A superintendent noted that guests "can provide their own shade. So they'll have an awning or even just in the shade of the camper they'll have somewhere to sit outside that's going to be just a little bit out of the heat that is not going to have as great an effect on how they spend their day." In addition to what guests provide, parks modify and **adapt campsites and cabins** to make them drought-ready: fire pits have designated locations and if it is exceptionally windy, campground hosts will circulate and educate guests about fire risks.

4. Discussion

Participants noted different signals when droughts occur. These signs, sometimes delayed, prompted various reactions. In this discussion, we consider how the observations related to the onset of drought and its subsequent effects can contribute toward improved management practices for parks.

4.1 Perceptions and definitions of drought

Participants had various conceptions about when a dry period becomes a drought. One mentioned a 2-3 week period without "much rain," and another mentioned two months of abnormal dryness, without specifying the amount of rain received. Being on par with a yearly average rainfall was viewed as a baseline for staying out of drought. Participants also noted hydrological dimensions of drought, stating that during a drought "water flows slow down."

Beyond changes in precipitation and stream flow, drought conditions include heat and wind. The manager at a prominent reservoir park mentioned that he viewed drought as synonymous with hot, sunny conditions with low winds.

Other managers interchanged hydrological conditions with the meteorological occurrence of drought. Lake levels were not a straightforward indicator of drought because participants noted management interventions and irrigation demand could draw lake levels down on a seasonal pattern. At one such lake, the manager noted that every April, the lake would be 100% full, but that by October, the levels would be down to 45-55% capacity. So to recognize a drought period, participants compared drought conditions to longer-term trends and generalizations about the state's climate features. One participant noted the lower precipitation levels of summer, stating, "Western Nebraska is truly a desert in July and August. You're lucky if you get a couple inches of rain each month…" Another mentioned when asked about conditions this year, "I mean, we're dry right now, but I wouldn't say we're in a drought. This is a normally dry area, you know."

One manager said that since his park is located closer to an urban area (Omaha), weather did not affect the park. However, in the same comment, he went on to mention that when nearby Elkhorn or Missouri Rivers are flooding or dry, members of the public call and ask whether the recreation area is still open. The manager seemed perplexed that conditions on these neighboring rivers would enter visitors' minds when thinking about visiting a park that is on the Platte River. However, the attribution of broader regional climate conditions to a localized area is common in the sector, as tourists tend to make decisions based on general perceptions (Becken, 2010). Managers also hold beliefs about their parks grounded in their local communities and the surrounding ecosystems. One superintendent said his large forested area in the northwestern part

502 of the state varied quite a bit from the rest of the state, bordering on confusing ecological
503 components for social dimensions: “Yeah, it’s actually a totally different culture, you know, with
504 the pine trees and the butte hills up here, it’s really neat.”
505 Though there is no singular definition across the parks, a set of themes emerged for a
506 conceptual definition of recreational drought. It is a shortage of naturally available water needed
507 for vegetation health, to support lake sports, to prevent permanent damage to park infrastructure,
508 and maintain visitor volumes needed for economic stability. As a starting point, this definition
509 provides room for establishing criteria specific to each site. The measurement of drought is
510 dependent on the climatology, ecology, and socio-economic context of each park.
511
512 *4.2 Recommendations for monitoring and management*
513 Follow-up management actions can enhance future drought resilience. After the last
514 drought of record, work crews at Chadron State Park thinned trees to reduce future risk of fire. In
515 October of 2012, the superintendent recalled a large snowstorm that led to broken branches and
516 cattle relocation in nearby areas. The superintendent speculated that the fire stressed the trees,
517 opening them up to risk of disease and insect infestation, including the pine beetle. The large
518 precipitation events following a dry period can damage trees (the snowloads break branches),
519 and lightning can ignite fires during thunderstorms. At Calamus Reservoir, prescribed burns
520 were previously not permissible. Following the drought of 2012, though, it became evident that it
521 was worthwhile to mitigate fire risk. Because of the fires associated with the drought, the
522 benefits of restoring native prairie grasses become more apparent and Game and Parks was
523 subsequently allowed to burn.
524 Park superintendents generally reported using shorter-term meteorological and

525 hydrological monitoring data sources. Weather information can inform daily decision-making
526 and helps managers recognize when certain areas may be at immediate risk of flooding.
527 However, in addition to keeping stock of daily fluxes, there is an opportunity to build longer-
528 term seasonal and annual monitoring into management activities. Putting precipitation amounts
529 into the context of long-term records would help in recognizing evolving conditions in a timely
530 fashion. Building this long-term monitoring would foster a decision-making context that is
531 informed by past drought experiences.

532 "Percent of normal" is a simple technique for understanding how precipitation in one
533 year compares to others (Svoboda and Fuchs 2016). Putting long-term data into perspective
534 assists managers in understanding when a drought is occurring and how severe it may be.
535 Tailoring drought management activities for recreation and tourism may require a park-level
536 inventory of land, water, vegetation, and wildlife resources. An opportunity exists to build these
537 activities into a park management plan as longer-term spatially referenced products would build
538 context for each location. Research compiling this type of need could be useful for building
539 future resilience because it may help to inform a comprehensive local drought definition. In
540 support of this goal, a local park drought definition would provide a platform for managers to
541 work across agencies, and to plan ahead for dry years, ensuring the park receives enough water
542 to maintain operations during dry years.

543 In their professional networks, park managers might find it useful to incorporate
544 conversations about low-cost drought coping measures. Workshops with water educators and
545 natural resource professionals may spur these conversations, but a lasting ethic of drought
546 resilience will involve ongoing reflection on the value of public lands and water availability for
547 non-consumptive uses. Once these collective goals are set, it may be possible to funnel these

548 needs up through the agency and request additional consideration of recreation when considering
549 environmental policies. Connecting outdoor recreation with ecosystem health may be another
550 avenue to bolster policy support for the economic benefits produced by the sector.
551 Drought mitigation requires understanding the chain of reactions that follow decreased
552 water availability, and requires the proper coalition of actors to agree on the appropriate
553 indicators and actions. As momentum builds for recommending mitigation guidelines, it may be
554 necessary for the drought research community to tailor monitoring products for public lands and
555 assessing ecosystem health. In the meantime, managers are compensating for dry conditions by
556 prioritizing irrigation around central entrance buildings and high-use visitor facilities, rather than
557 individual campsites. Though it may be difficult to make these choices, creating a priority list for
558 watering zones may be a way to maintain a sense of normalcy that green grass brings.
559
560 **5. Conclusion**
561 In sum, park managers expressed varying levels of concern for formally monitoring
562 drought. Where applicable, they use a variety of sources, including federally produced climate
563 information, commercial products, as well as their own observations and intuition. Drought
564 impacts on recreational activities vary with a park's climate, ecological features and built
565 amenities. The techniques used to measure visitor trends vary by park, but managers shared the
566 desire to monitor usage rates. Managers had a general sense of trends in visitor volume trends
567 and seasonal change as well as how drought affected recreational choices.
568 Droughts have affected state parks more in some years than others have, with the recent
569 2012 drought standing out as particularly devastating for vegetation health and wildfire
570 outbreaks. Some of the effects from this drought are still lingering, such as die-off of lakeshore

571 cottonwood trees. Not all droughts are as long lasting, and can affect parks during the course of a
572 single season. Droughts impacts change with the time of year. Managers noted that they are
573 concerned in the spring with vegetation health, particularly for young trees or newly planted
574 areas; reservoir levels during irrigation season and heat impacts on visitors during the summer;
575 hunting and fishing accessibility during the fall; and infrastructure maintenance during the
576 winter.

577 When droughts occur, managers implement a range of actions to protect recreators,
578 maintain the landscape, and cooperate with surrounding landowners and co-governing agencies.
579 Superintendents demonstrated a deep understanding of the role of water availability in ecosystem
580 functioning. They related interstate basin-wide flows, reservoir management and groundwater
581 withdrawal to soil, plant, and animal health. They are using practical measures to conserve water
582 and maintain the park under changing conditions, but may not always relate these practices back
583 to drought management.

584 Several opportunities exist to advance park management toward drought resilience.
585 Currently, managers tend not to formally monitor drought and instead focus on short-term
586 weather conditions, rather than longer climate trends.[18] Given the magnitude of potential losses
587 for the outdoor recreation sector, it would be advantageous for park managers to have a readily
588 accessible system with a set of indicators to assess the occurrence of drought and the necessary
589 series of actions that follow. Connecting a spatial product such as the U.S. Drought Monitor with
590 park communications may provide an early warning when droughts set in. Connecting this with a
591 management plan or task force would prepare parks for droughts before they occur. Many of the
592 appropriate actions are already underway, and future preparation could be as simple as
593 documenting current adaptation strategies.

[18] Daily weather reports are not generally considered adequate for drought monitoring activities.

6. Disclosures

The authors declare that they have no conflict of interest. Informed consent was obtained from all individual participants included in the study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards**.**

7. Appendix: State Park and Recreation Area locations, date of interview, and park resources

Location	**Date**	**Land Area**	**Lake Water Area**	**River and Stream Extent**	**Hiking Trails**	**Shoreline Miles**
Mahoney State Park	22 August	2.3 km^2 †	Park lakes and marina	Platte River channel	10 km†	-
Lake McConaughy State Recreation Area	24 August	21 km^2	140 km^2	-	-	>161 km
Fort Robinson State Park	24 August	89 km^2	Carter Johnson Reservoir	Soldier Creek	97 km	-
Lake Wanahoo State Recreation Area/Sand Creek Watershed Project	28 August	7 km^2 •	3 km^2 **	-	Several mowed wildlife trail areas	-
Two Rivers State Recreation Area	31 August	2.5 km^2	1.3 km^2 in sandpit pond lakes‣	Adjacent to the Platte River	-	-
Lewis and Clark State Recreation Area	12 September	5 km^2 ∞	121 km^2 ∞	Missouri River	-	145 km×
Chadron State Park	13 September	>4 km^2 *	Lagoon/pond	Chadron Creek	10 km	-
Calamus State Recreation Area	19 September	20 km^2	21 km^2	1.6 km Calamus River and other streams	-	58 km of white sand
	Totals	152 km^2	287 km^2	~	~	364 km

Unless otherwise noted, all data were obtained from the Nebraska Game and Parks Agency website or personnel. Missing values are demarcated with a ' – .' *Reported over telephone by park personnel 22 November 2017. ** Bathymetric data available at: https://maps.outdoornebraska.gov/lakemaps/ † Johnsgard 2001 • Lower Platte North Natural Resources District http://www.lpnnrd.org/projects/recreation/wanahoo.html ‣ Nebraska Game and Parks Reservations https://nebraskastateparks.reserveamerica.com/camping/two-rivers-sra/ ∞ Nebraska Birding Trails "Gavin's Point Dam information available at: http://nebraskabirdingtrails.com/gavins-point-dam-and-lewis-clark-lake-state-recreation-area/ × US Army Corps of Engineers – Gavins Point Recreation Areas information available at: http://www.nwo.usace.army.mil/Missions/Dam-and-Lake-Projects/Missouri-River-Dams/Gavins-Point/

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706 **9. Tables**

707 Table 1. Content and intent of interview questions.

	Question	Intent	Time (min)

1.	Have you seen park visitation change in the recent past? Are there any patterns to park visitation and have they changed? *1a. What activities is your park known for?*	Introduction to the park, beyond what is known beforehand from the agency website and promotional materials. To get brief context of how outdoor recreation is affected by drought in that park or part of the state.	4
2.	How are conditions this year? Are you experiencing a drought?	To obtain current perceptions (can be compared with USDM map).	4
3.	When was the last major drought event? What happened during the last major drought event?	Gauge recollection of timeframes and severity of impacts. Could reveal differential park impacts. Reconstruction of past drought impacts.	5
4.	Sometimes fish and wildlife may be affected by dry conditions. Are there ecosystem impacts that go beyond how park visitors perceive a drought? What are the general impacts of drought in each season?	Gauge the area's seasonality of drought. To understand if drought's effect varies depending on the time of year that it occurs in. Full range of fall, winter, spring, and summer would be desirable to know. *Some examples could include:* -changes in erosion/sedimentation -wildflower blooming cycles -wildlife movement	5
5.	What information sources are used to monitor drought? How do you provide that information to visitors?	To assess the use of operational monitoring products, and other observational data points. Since drought is a locally-defined event, this question gets at the conditions that are important to local managers. The prompt also allows interviewees to elaborate on their communications strategies.	3
6.	Are there any safety precautions, or management practices, taken during drought?	To understand what management concerns exist during drought, whether they are for ensuring visitor safety or ecosystem functioning.	4
7.	What effect does drought have on park visitation? *What are the impacts of increased/decreased visitation on the park?*	To contextualize the quantitative portion of the analysis, and provide an observational account of statistical trends. Gauge the superintendents' attribution of drought to social outcomes in the park.	5

731 Table 2. The codes developed for the thematic content analysis designed to match the research
732 questions.

Code name	Description
Drought and Climate Monitoring Sources	The place that managers go to find information about temperature and rain, or the trends over time.
Drought Conditions this Year	How superintendents perceive drought impacts this year, what the conditions have been like at the park in the recent months.
Drought Impacts	What are the general and observed effects of drought in the park, including both currently and historically.
Regulatory change	The policy impacts or tag-on effects that govern the jurisdiction or sector.
Seasonal Variation	Are there different effects connected to the timing of a drought?
General Ecological Features	What are the general ecological features of the park and the area?
Hydrological Systems	How does the larger basin or watershed area affect what happens in the park, and what are the ways that managers observe these effects?
Last Major Drought	When was the last major drought event, and what was the timing and onset?
Management Actions	How do superintendents maintain park spaces and keep visitors safe during drought? These actions can be status quo/maintenance-focused, or can be additional above-and-beyond measures.
Methodology	The qualitative interviewing characteristics of the method
Intent	the basic intent and goals of the research
Researcher perspective	The researcher as interviewer
Park Activities	What are the main activities the park is known for?
Park Communications Strategy	How information about drought is relayed to visitors and the general public
Visitation Trends	Document observations about the fluctuations in park inter-annual and seasonal trends, or how these data are collected.
Drought Effects on Visitation	Observations, thoughts, perceptions on how drought affects visitation trends.
Effects of visitation on the park	How does a change in visitation affect the park?
Superintendent methods	Data collection on behalf of the parks about visitors
Visitor Origin	Where visitors come from
Visitor Segmentation	Why they are going to the park

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745 Table 3. Major activities emphasized in each park according to the superintendents. (Source:
746 Interview data)

Location	Superintendent-emphasized activities
Mahoney State Park	Lodge, cabins, electric padded campsites, picnics and water park (wave feature, pool with dumping buckets), melodrama theatre, family reunions, indoor playground, ice-skating rink, toboggan hills, interactive naturalist center, year-round arts and crafts, marina lake, paddle boarding lake, kayaking and canoeing
Lake McConaughy State Recreation Area	Largest state reservoir with a focus on water-based recreation, motorized boating, kayaking, canoeing, RV camping, tent camping, beach parties, fishing
Fort Robinson State Park	Former military outpost with officers' quarters, equestrian groups and trail riding, family reunions, inner tubing, kayaking, swimming pool, big game hunting, bison and longhorn cattle, bighorn sheep and other wildlife viewing
Lake Wanahoo State Recreation Center	Fishing [Northern pike, blue catfish, panfish (sunfish and crappies), largemouth bass, and walleye are stocked], campsites (50% RVs), boating, river access
Two Rivers State Recreation Area	Trout lake, river activities, irrigation supply ponds, irrigation wells, small game and waterfowl hunting, and archery
Lewis and Clark State Recreation Area	Water recreation on Nebraska's second-largest reservoir, speedboats, jet skis, tubing, sailing, kayaking, paddle boarding, marina, convenience store with snacks
Chadron State Park	Hiking in pine bluffs and buttes, wildlife viewing (bighorn sheep, mountain lions), marathon and triathlon races, quiet firework-free Fourth of July celebration, nearby rodeo and Fur Trade Days, camping, cross-country skiing, sled hill, fishing, horseback riding, pool
Calamus State Recreation Area	Lake recreation, power boating, jet skiing, water skiing, white sand beaches, deer hunting, duck hunting, upland game hunting

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749 Table 4. Drought monitoring information sources.

Source of information	Rationale and additional comments
Little-to-no formal operational monitoring activity	• Since drought is a long-term phenomenon, do not see a need to monitor. • Reliance on anecdotal knowledge of weather, for example watching rainstorms and their patterns. • Participant reports not needing to monitor drought since the park is located in the more humid part of the state.
Fire index County burn bans	• Superintendents mentioned working with the local fire department because they "are paying closer attention." • Participant expressed a general desire to "have an awareness" of where the fire danger is.
Commercial weather providers	• Local weather channel; weather service outside of North Platte. • Non-specific sources of climate information available on the Internet
Short-term publically-provided products	• Game and Parks central office sends direct messages to the Superintendents. • Data from the Central Nebraska Public Power and Irrigation District weather station. • National Weather Service – e.g. precipitation levels. • Stream gauge alerts and text messaging with notable changes.
Long-term publically-provided products	• The US Drought Monitor. • Annual precipitation averages.

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751 Table 5. Drought impacts by ecoregion (source: interview data). Ecoregion classes are
752 determined from the criteria and spatial extent outlined in Schneider et al. (2011).
753

Ecoregion	Drought Impacts
Tallgrass Prairie near the Platte River	• Newly seeded areas dry up. • The grass is dry and "crispy" around cabins. • The aquatic center is "considerably busier" with hotter, drier weather.
Tallgrass Prairie with fishing lakes	• Campers exposed to additional heat in their tents or in the sun. • Walleye and pike fish move to deeper and cooler parts of the lake. • Newly planted tree saplings at risk. • Changes in trout lake water levels affect fishing. • Outbreak in Epizootic Hemorrhagic Disease (EHD) disease affect many deer in Eastern Nebraska.
Tallgrass Prairie with reservoir on the Missouri River	• The leaves on trees start to wilt, even in the early part of the day when they normally do not. • New tree seedlings were not growing as expected. • Grass does not grow as expected. • Grassy areas around roads and buildings is brown and hard.
Tallgrass Prairie on the Missouri River	• Deer struggling to find forage, begin feeding on planted hosta garden. • The swimming pool became very busy as people sought out water.
Shortgrass Prairie at higher elevation	• Severe wildfire required closing the park. • Erosion in campground areas, with dirt washing down and settling on campground pads.
Shortgrass Prairie historical park	• Hay fields and grazing areas were dry.
Border of Sandhills and Shortgrass Prairie	• Significant decline in the reservoir levels. • Tree mortality at immediate and delayed time intervals. • Yards of additional beach expansion with decreased water levels, with multiple vertical feet per week.
Sandhills Reservoir	• A fifth of the boat docks remained accessible. • Shoreline shifts with historically low water levels. • Sand blew in places it had not previously been, creating peninsulas and closing off bays. • Some boats got stuck on the shifting sand hazards. • Small wildland fire. • Cottonwood trees growing in places they had not previously, as standing water gave way to wet soils. • An increase in brome grasses, more than non-native bluestem species. • Significant EHD breakout that affected the deer population. • Trees were initially affected but rebounded several years later.

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771 Table 6. Drought impacts by season, as noted by participants.

Spring	• Increased brome grass, and less non-native bluestem species. • Water stress on trees. • Prescribed burns may be delayed. • Earlier snowmelt can change the popular fishing locations. • Pollinator plots and wildflower blooming affected.
Summer	• Newly planted areas at risk. • Reduced number and decreased length of horseback trail rides. • Increased use of marina areas, paddleboats, and water features. • Ecological lake effects: fisheries will be harder to access. • Walleye and Pike anglers reduced. • Increased social agitation and additional correctional contact required with misbehaving visitors. • Some boat ramps are not usable in lower water levels.
Fall	• Change in turkey hatches. • Differences in visitor perceptions of wildlife (notably deer). • Changes in Sandhill stream flows.
Winter	• Reduction in snowfall results in a failed cross-country ski and snowshoe season. These trails did not need to be maintained. • Temperature and snowfall can affect the feeding requirements for livestock. • Supply lines freeze in dry ground, delivering water to cabins on hillsides in the open. • Low-snow years set up the spring for fire risk. • It can take longer for grass and plants to begin growing in transition to spring.

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774 **10. Figure Captions**

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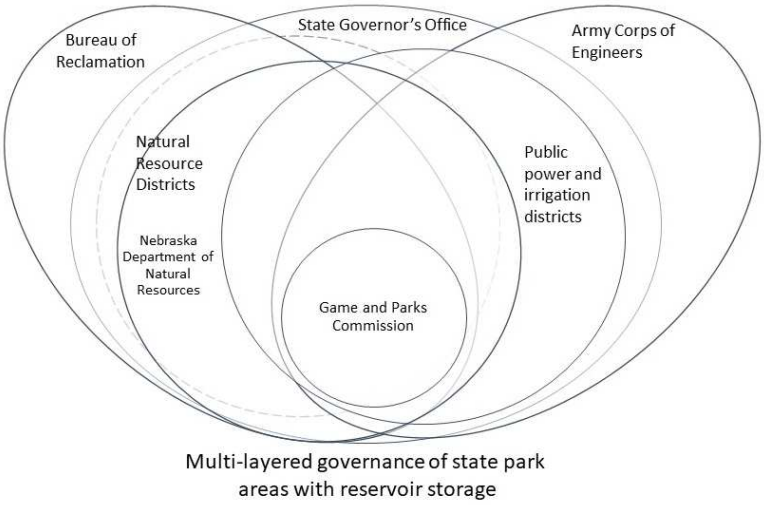

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777 Figure 1. Multi-layered governance of Nebraska state park areas with reservoir water storage.
778 Created by authors with information on Natural Resource Districts in Herpel, 1995 and Central
779 Platte NRD, 2011; public power and irrigation districts from Nebraska Public Power District,
780 n.d.; and Nebraska Department of Natural Resources, 2009.
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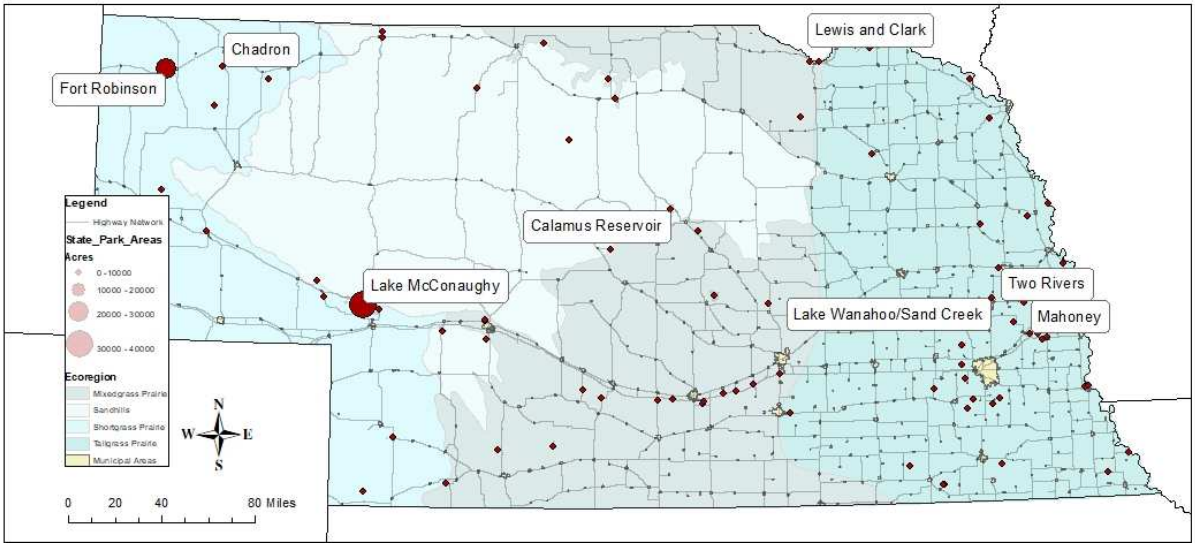

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783 Figure 2. Study sites: Nebraska state park and recreation area locations.

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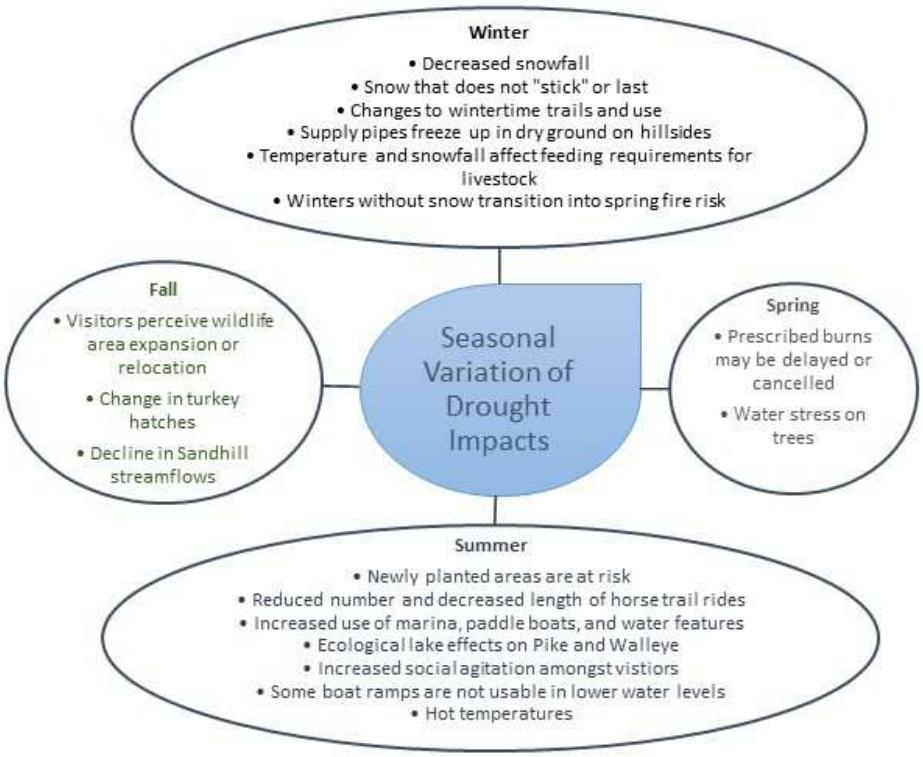

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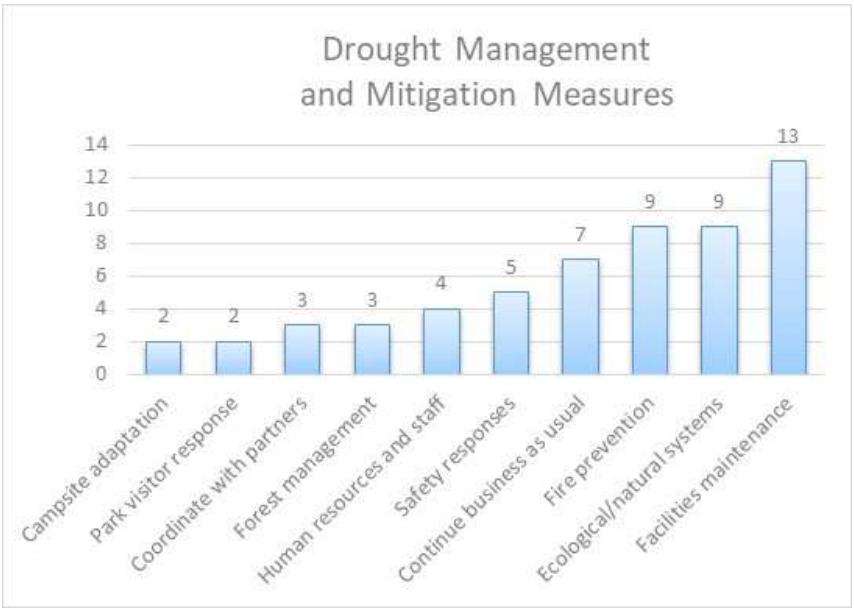
786 Figure 3. Seasonal impacts of drought reported by Superintendents.



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788 Figure 4. Superintendent park drought mitigation and management responses.