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ABSTRACT

Ecosystems around the world are experiencing unprecedented anthropogenic impacts, emphasizing the need for a nuanced understanding of how individual decision-making shapes social-ecological systems. In rangeland systems, prescribed fire can reduce woody plant encroachment, restore the resilience of native grasslands, and mitigate fuel load accumulation limiting catastrophic wildfires. Yet, many individuals decide against this land management practice. In order to better understand the cognitive decision-making processes that shape the use of prescribed fire in rangeland ecosystems, we conducted 66 semi-structured interviews with key informants in the Texas and Oklahoma portions of the Southern Great Plains. Results indicate that heuristic processes were frequently used when considering the use of prescribed fire, but that analytical processes were more likely to lead to prescribed fire implementation. These findings suggest the need to reframe prescribed fire communications to the public, rethink prescribed fire regulations, and reshape liability insurance for fire practitioners.

Introduction

Rangelands are globally experiencing a shift away from grass-dominated to woody plant-dominated ecosystems (Twidwell et al. 2013). This conversion has been especially pronounced in the Southern Great Plains (SGP) of Texas and Oklahoma where woody plant encroachment has been five to seven times greater than in other areas of the country (Barger et al. 2011). In this region, once dominant grasslands have experienced significant shifts in vegetative composition due to the expansion of Euro-American farming and ranching during the last 200 years (Wilcox et al. 2018). At the same time, the SGP's historical fire regime, comprised of both anthropogenic and natural ignitions, has been heavily suppressed (Twidwell et al. 2016). The region's migratory bison herds were also nearly eradicated, reduced from an estimated 30–60 million to no more than a few thousand during the 19th century (Knapp et al. 1999). The geographically

heterogenous biotic and pyric herbivory drivers responsible for sustaining herbaceous production and suppressing woody plant encroachment were largely eliminated. Similarly, where open savannas once existed with riparian gallery forests and wooded rocky escarpments, woody plant encroachment began to shift the vegetative community to a shrubland.

This shift in the vegetative community has had numerous impacts on the SGP and its inhabitants. Wilcox et al. (2018, 696) note that "Forage production and wildlife habitat are among the most important of the various ecosystem services that directly affect livelihoods" in the SGP. This shift has negatively affected livestock operations via decreased forage production (Wilcox et al. 2018), while society at-large has been impacted by increased variability in carbon sequestration capacity (Barger et al. 2011; Twidwell et al. 2013) and heightened wildfire threats to both rural and urban areas from accumulated woody plant biomass (Blanchard and Ryan 2007; Twidwell et al. 2013). Additionally, ground-nesting birds, such as the greater and lesser prairie chicken and the northern bobwhite, have experienced habitat degradation as the species' favored bunchgrasses were outcompeted by woody plants (Engle, Coppedge, and Fuhlendorf 2008). This degradation of historical grasslands and savannas has led to decreased avian and other biodiversity throughout the SGP (Engle, Coppedge, and Fuhlendorf 2008). Ultimately, these vegetation shifts have negatively affected the resilience of these historically productive ecosystems and associated human wellbeing in the SGP.

Prescribed fire is the purposeful ignition of fire under specified weather and fuel conditions (specified wind speed, air temp, live fuel moisture, etc.) in order to mimic the system's historical fire regime. The use of this land management tool can mitigate the effects of many of the vegetation shifts experienced in the SGP by reducing volatile woody plant fuel loads and promoting herbaceous production (Taylor et al. 2012). However, prescribed fire has been underutilized (Weir 2010; Toledo et al. 2012), which, together with active fire suppression since Euro-American expansion, has effectively eliminated the role of fire as a landscape-scale abiotic driver of the region's historically herbaceous-dominated plant community (Axelrod 1985). The resistance to the use of this land management tool has persisted despite the impressive nationwide safety record of prescribed fire compared to other commonly used agricultural practices (Twidwell et al. 2015; Weir et al. 2019). As Twidwell et al. (2015, 9) state, the "data universally suggest that current risk aversion driving the preference for alternative land management techniques over prescribed fire is not supported."

A social factor in this underutilization is the decision-making process individuals employ when considering the implementation of fire. Many decision-making models frequently utilized in natural resource decision-making (Riechers, Conner, and Heitschmidt 1989; Beukes, Cowling, and Higgins 2002; Yoder et al. 2003) oversimplify the complexity of dynamic social-ecological settings (Beratan 2007). Specifically, such frameworks do not adequately address the reliance of decision-making on heuristics (Kahneman 2011; Gigerenzer and Gaissmaier 2011). The inclusion of heuristic processes when considering prescribed fire usage is key to understanding an individual's willingness to use this land management tool.

Theoretical Framework

Human decision-making has traditionally been based on the theoretical model of *homo economicus* or "economic man" (Edwards 1954), which focuses on an individual's rational utility maximization and was popularized by late 19th-century economists (Smith 1776). As referenced in natural resource management literature, this model assumes decision makers have perfect information, infinite time, and limitless analytical power (Ostrom 2000). While this model may suffice in certain narrow natural resource contexts (e.g., timber sales), these assumptions are rarely realistic, thereby limiting the predictive ability of the *homo economicus* model for a decision that is as multifaceted as the implementation of prescribed fire. The limits of *homo economicus* have been widely recognized (Doucouliagos 1994; Thaler 2000). However, the model is referenced extensively in natural resource literature, likely due to its easy application across a wide range of decision-making settings (Riechers, Conner, and Heitschmidt 1989; Beukes, Cowling, and Higgins 2002; Yoder et al. 2003; Teague et al. 2008; Teague et al. 2009).

Other conceptualizations of individual decision-making, such as Simon's Theory of Bounded Rationality (1956) and dual-processing accounts of human behavior (Evans 2008; Stanovich and West 2000), more closely model real-world constraints. Rather than assuming perfect decision-making environments in which a single, highly structured, conscious process leads to utility maximization, these models suggest a dual-process decision-making system distinguishing between a System 1 (unconscious, rapid, automatic, and high capacity) and System 2 process (conscious, slow, and deliberate) (Evans 2008). System 1 is characterized by being pragmatic, associative, implicit, contextualized, and emotional whereas System 2 is characterized by being explicit, analytical, sequential, and logical. In reality, neither system adequately describes human decision-making, especially in modern societies where many decisions must be made daily. The two-system model also ignores formal models of heuristics and how decision-makers operate in a rational manner bound by environmental and cognitive constraints (Gigerenzer and Selten 2001).

In practice, intuitive processes are referred to as heuristics (Todd 2001) and refer to strategies that ignore information to make decisions faster, more frugally, and/or more accurately than more complex models (Gigerenzer and Gaissmaier 2011). While the *homo economicus* model is concerned with utility maximization in choice, heuristics focus on finding a solution that is satisfactory rather than optimal (Selten 2001). This approach is called "satisficing," a term coined by Simon (1956, 129) to describe the search for satisfactory, rather than optimal, solutions. The need to satisfice arises from limitations in the choice environment such as finite time, imperfect information, and limited cognitive capacity. While heuristics are unlikely to generate optimal solutions, they provide decision makers an intellectually inexpensive process to navigate the multiple decisions in daily life that seldom require optimality.

Heuristics are a type of mental shortcut allowing individuals to implement cognitive "strategies for estimation, comparison, and categorization" (Martignon 2001, 147) in a relatively fast, efficient manner. Generally, heuristics refer to an "adaptive toolbox" of sub-strategies that include "recognition" (e.g., if one of two alternatives is recognized, the recognized alternative has a higher value), "fluency" (e.g., if both alternatives are recognized, but one is recognized faster, that alternative has a higher value), and

"one-clever-clue" (which bases a decision on a single compelling reason only), to name a few (for full review see Gigerenzer and Gaissmaier 2011). Our researcher focuses primarily on the application of the affective heuristic, which is one such process that refers to the binary positive or negative emotional tags individuals have been shown to associate with memories (Finucane, Peters, and Slovic 2003).

When considering the use of heuristics in the implementation of prescribed fire, contemplate the following hypothetical. As research has indicated, an individual's opinion of prescribed fire can be influenced by the manner in which media coverage of fire-related issues is framed (Tversky and Kahneman 1981; Ascher, Wilson, and Toman 2013; Twidwell et al. 2015). Landowner 1 has been considering the use of prescribed fire on his property. He recalls a local news report detailing the damage caused by an escaped prescribed fire and the negative emotional tag he associates with that memory, and he has no other fire-related information. Landowner 2 is also considering implementing fire, is relatively uninformed about fire, but remembers a different report stating that regular prescribed burning likely reduced the intensity of her state's last wildfire season. This memory would have a positive emotional tag for prescribed fire. Thus, it is likely that Landowner 1's negative emotional tag would predispose him to not implement prescribed fire via use of the affective heuristic. Conversely, Landowner 2's positive emotional tag would likely lead her to implement prescribed fire utilizing the same decision-making process.

While the actual decision to use fire is decidedly more complex, this example illustrates two points. First, it provides a hypothetical example of how heuristics might be used to make fire-related choices. Secondly, it demonstrates that heuristics are a powerful, semi-conscious, value-neutral tool capable of being applied to reach both factually substantiated and unsubstantiated decisions (Gigerenzer and Selten 2001). Given prescribed fire's exemplary safety record, the decision to consistently not implement the tool based on the heuristic processing of a single data point can reasonably be considered a misapplication of heuristics.

Heuristics have been documented in a variety of decision-making contexts across multiple fields (Gigerenzer and Selten 2001), including the use of prescribed fire (Ascher, Wilson, and Toman 2013; Wilcox et al. 2018). Dupéy and Smith (2018, 1012) state that understanding heuristic use as it pertains to fire is essential as individuals often "make snap judgments based on perceptions, attitudes, [and] prior experience … that can have long term consequences which are not apparent while making the decision." Wilcox et al. (2018, 698) list the affective heuristic as being an important tool in an individual's choice to implement fire, especially in instances where the individual has "little to no previous experience" with the practice. This use of the affective heuristic in this context represents an attempt to streamline a complex decision-making process. Ascher, Wilson, and Toman (2013) go even further in claiming that heuristic processes have likely negatively influenced wildland-urban interface residents' opinions on prescribed fire in the Intermountain West after they viewed sensationalized media coverage.

It is likely that many individuals make certain decisions largely informed by heuristic processes, other decisions via analytic processes, and yet others through a dual-process approach. However, the relative frequency with which these decision-making processes are

used by those making decisions about the implementation of this land management tool remains uncertain. The investigation reported here sought to address those knowledge gaps. Better understanding of the use of heuristics will improve insight into individual fire implementation decisions in an effort to implement the tool at a landscape scale in the SGP.

Objective and Hypotheses

The objective of the research was to highlight instances of analytic, heuristic, and dual decision-making processes and the associated outcomes in decisions to implement prescribed fire. This objective was operationalized by testing two related research hypotheses:

Hypothesis 1: Affect heuristic decision-making processes are used more often than analytical processes when making the decision to use prescribed fire (Stanovich and West 2000).

Hypothesis 2: Analytic processes lead to the decision to implement prescribed fire more often than affect heuristic processes (Ascher, Wilson, and Toman 2013).

Methods

Study Area

This study focused on the SGP of central North America. This portion of the Great Plains encompasses eastern Colorado and New Mexico, nearly all of Kansas and Oklahoma, and the entirety of northern and central Texas, extending as far south as the Gulf of Mexico (EPA 2016). This investigation focused on the central portion of the SGP found in Texas and Oklahoma.

Data Collection

Data collection consisted of 66 key informant interviews conducted by three interviewers between May and August 2017. The initial three key informants in both states were identified by a project "gatekeeper" (Keesling 2011, 2) who was well integrated into the respective state's prescribed fire culture. A purposive snowball sampling method was utilized thereafter, whereby the initial six interviewees were each asked to recommend two additional potential interviewees, who in turn were also asked to recommend potential additional interviewees. Ideally, these recommendations included both burn practitioners and non-practitioners. Representatives were sought from federal agencies, state agencies, nonprofits, burn associations, and private landowners or ranch managers in both states. The breakdown of the sample can be found in Table 1.

The interview process was terminated when data saturation was achieved, and new interviewees began to consistently provide similar responses as the preceding interviewees (Bernard 2000).

The interviews followed a semi-structured format using a predetermined series of ordered questions with substantial opportunity for open-ended responses (Bernard 2000). Examples of questions used during the interview process include:

Table 1. Interview sample characteristics.

Entity	Interviewees	Percentage of sample
Federal Agencies (including National Resource Conservation Service; U.S. Fish and Wildlife Service; Oaks and Prairie Joint Venture)	7	11%
Oklahoma State Agencies (including Oklahoma Conservation Commission; Oklahoma Cooperative Extension Service; Oklahoma Department of Agriculture, Food, and Forestry; Oklahoma Department of Wildlife Conservation)	10	15%
Texas State Agencies (including Texas AgriLife Extension Service; Texas Forest Service; Texas Parks and Wildlife Department)	14	21%
Non-governmental organizations (including Katy Prairie Conservancy; Oklahoma Cattlemen's Association; The Nature Conservancy; The Noble Foundation; ESD)	13	20%
Prescribed burn associations AND Fire management associations	14	21%
Private landowners, private contractors, and ranch managers	8	12%
Total Interviews	66	100%

- What is your opinion of prescribed fire as a brush control/land management tool? What information sources or experiences informed this opinion?
- Have you personally experienced or been involved with prescribed fire? If so, please explain how?
- In general, do you support the use of prescribed fire? Please explain?
- In general, would you describe your land management decisions as risk-averse, risk-neutral, or risk-prone? Please explain your response in the context of land for which you provide management advice.
- Have you personally participated in the application of prescribed fire?

Interviews were conducted by telephone due to the large study area and were recorded. This protocol was approved under IRB # 2017-0364. While it was necessary to discuss several key issues related to prescribed fire identified by the research team, it was deemed equally important to remain receptive to new issues that arose. This use of incoming data to inform methodological changes is consistent with Grounded Theory (Ji and Eun-Hee 2014) and provides methodological guidance in a qualitative and iterative investigation. While interviewees were free to discuss any related issues they deemed appropriate, predetermined interview questions focused on three main areas of interest: (1) the interviewee's past history with prescribed fire and wildfire, (2) the interviewee's attitudes and perceptions regarding the benefits and risks of using prescribed fire, and (3) the interviewee's familiarity with their respective state's statutes on prescribed fire liability.

Data Analysis

The recorded interview responses were transcribed by a professional transcription service and uploaded to NVivo 12 Plus, a qualitative data analysis program (NVivo 2019). Three independent coders then conducted stage one of a three-stage thematic analysis approach (Williams 2012).

The approach began with an emergent themes analysis with all coders reading a collection of 12 interviews. Themes that emerged in the transcribed data were identified independently by each coder and were then compared. Inter-coder themes with large content overlap were combined to create a master theme list that included three major themes: (1) cognition concerning and perception of prescribed fire, (2) communication about prescribed fire, and (3) utilization of prescribed fire. Coders then read each interview three additional times, only coding for a third of the master list on any given reading to ensure coding accuracy. Intercoder reliability was determined utilizing percent agreement as well as Cohen's kappa metrics (Lombard, Snyder-Duch, and Bracken 2004). These two metrics were used because percent agreement does not account for the amount of intercoder agreement due to random chance, whereas Cohen's kappa does (Lombard, Snyder-Duch, and Bracken 2004). Thus, the combined metrics provided a more robust method to ensure that instances of emergent themes were appropriately coded. Percent agreement of coding between each pair of coders averaged 96%, with >90% representing high agreement (Lombard, Snyder-Duch, and Bracken 2004). The average Cohen's kappa was 0.73, with a range of 0.60–0.80 considered "substantial agreement" (Viera and Garrett 2005). These results suggest the themes observed by the coders are objective and accurate representations of the themes present in the data.

During stage two, the coded stage one data were analyzed, revealing a latent theme that had previously not been clearly identified. Examination of the coded data revealed the prevalence of affect heuristic processes in decisions about the implementation of prescribed fire. These processes were not explicitly coded for in stage one but were captured imperfectly by the themes of "cognition concerning and perception of prescribed fire" and "utilization of prescribed fire," as Grounded Theory would suggest (Ji and Eun-Hee 2014). Analysis of those themes revealed these processes as variables likely impacting prescribed fire implementation. Consequently, a second thematic analysis that focused on decision-making processes was conducted. A single coder analyzed all interviews for any instances of decision-making in the context of prescribed fire implementation. This analysis produced a new "decision-making" theme of interview excerpts. Any given interview may have been coded for multiple instances of decision-making.

In the third stage, individual excerpts comprising the decision-making theme were coded by a single coder to one of three decision-making process categories with respect to the implementation of prescribed fire: analytical, heuristic, and dual-process. The decision to utilize prescribed fire was coded from the qualitative data primarily in response to two questions: (1) "Have you personally experienced or been involved with prescribed fire? If so, please explain how?" and (2) "Have you personally participated in the application of prescribed fire?"

Results

Affect Heuristics Present in Prescribed Fire

Our analyses revealed the extensive use of heuristics in decision-making regarding the implementation of prescribed fire. Thirty-three interviewees reported 73 discrete instances of decision-making about fire implementation or fire-related choices. On average, each individual that reported a discrete instance of decision-making about fire did so

twice during the interview (average number of instances per individual is 1.97). Sixteen individuals reported one instance, and one individual reported five instances (the maximum). A prescribed fire "decision" was generally defined as the recounting of a past action (e.g., past choices to implement or abstain from fire use, past fire involvement, etc.) or statements of current or past opinions on prescribed fire-related issues.

Of these 73 instances, interviewees reported using heuristic processes in 47% (34 instances) of decisions. Heuristic decision-making processes were defined as decisions in which interviewees used *only* emotive language to describe fire-related decisions:

> I've had to fight wildfires on our ranches and clean up after that and I know people that have both been hurt or killed in fires. **Fire is something you're always terrified of.** (PLPC1.5)

Analytic processes were used in 23% (17 instances) of decisions and were defined as instances in which interviewees discussed *only* using a quantitative process to make fire-related decisions. Analytic processes included choices utilizing cost-benefit analyses, strategic planning, or any other process that indicated systematic, conscious decision-making:

> In putting together my strategies [regarding prescribed fire] it is a lot **more cost effective** than trying to spray [chemical treatments]. (PLPC1.5)

Interestingly, a dual-process approach also emerged as an oft-used decision tool. Dual processes were used in 27% (20 instances) of decisions and were defined as choices in which both emotive language and quantitative processes were mentioned in making fire-related decisions:

> Well, the liability issue is a huge bugaboo. It is what scares more people away from fires that I can think of, second to **the cost** of actually preparing your property for it. A lot of ranchers are **scared off** by the potential of a wildfire getting out and having **liability issues**. (PLPC1.6)

Remarkably, on multiple occasions instances coded as dual process were in reference to liability issues. The issue of liability is at once both emotive and rational, as indicated in the quote.

In less than 3% of decisions, the processes used to decide not to implement prescribed fire were indeterminate.

These results confirm Hypothesis 1 that affect heuristic processes are used more often than their analytical counterparts in prescribed fire-related decision-making. While individuals seem to be neither perfectly analytical optimizers nor purely intuitive "satisficers," the processes they employ are often concentrated near one pole of the analytic-heuristic spectrum. Due to their economy of effort and the complexity of prescribed fire decision-making, heuristic processes are employed in a variety of ways. One ranch manager in Texas described an early foundational memory in her decision to use prescribed fire professionally later in life:

> I think [prescribed fire] is an excellent tool. I think that it is extremely valuable and necessary. [The] way that I learned about that is … we used to do some prescribed burning around our … 600-acre spread in the middle of [a] national forest [in Colorado]. [In 2002] we were hit by the Hayman Fire and, because the national forest never did any sort of brush management … that whole area just went up in flames. But, when it got to our place,

it … went around us, followed our fence line, and rejoined after us. **So, when you saw it from the air, it was just this little green eye in the middle of blackness. That's when I knew that prescribed fire is really valuable and really needs to be done.** (PLPC1.3)

This excerpt indicates usage of positive emotional tags associated with the aerial image of her family's unscorched ranch. Those tags were utilized via the affective heuristic by the individual years later when deciding to implement prescribed fire in a similar context.

Heuristic processes do not always rely on the memory of a single event. A Texas Parks & Wildlife (TP&W) employee described the incremental way many individuals come to accept prescribed fire as a legitimate rangeland management tool:

> … after most of our private land burns, we try to hold … a briefing on how the day went. The question that I … often ask when I … attend these [briefings] is, "Well sir, well ma'am, how did you feel about this? Do you think you might be able to do this in a couple years with a little more practice?" And they'll usually say, **"Well, it took me a while to get the nerve up to do this. It took me a while to feel like I could do it … But now I realize it's something I could do."** (TPWD1.1)

The individuals to which this survey participant referred were initially unfamiliar with prescribed fire, however, the quote illustrates a positive experience referenced via use of the affective heuristic.

Other individuals utilize heuristics from an early age when shaping their opinions about prescribed fire. An employee from the Oklahoma Department of Agriculture, Forestry, and Fisheries (ODAFF) described the way residents in one area of the state implement fire:

> … you go into central and eastern-central Oklahoma and there's no shortage of people burning their land. **Some of them don't even know why they do it, they just do it out of tradition, because their grandad did it.** (ODAFF2.1)

In this example, individuals developed a large bank of positively tagged memories of prescribed fire use from early in life, leading to strong heuristic use regarding this land management tool later. As the interviewee stated, while some individuals are unclear about the exact ecological effect prescribed fire has on their rangeland ecosystems, they continue to burn regularly due to many years of positive emotional associations with fire.

Heuristic Application regarding Prescribed Fire

Although relatively effortless and therefore frequently used, heuristic processes can also have negative cues associated with statistically low probability risks of prescribed fire, which subsequently leads to low tolerance for fire implementation. In instances where heuristic use drives an individual to make decisions not in agreement with the facts of prescribed fire, this disagreement often stems from systemic biases in the way heuristics function (Tversky and Kahneman 1974).

The following quote from a U.S. Fish and Wildlife employee highlights how heuristics can lead to generally false conclusions about prescribed fire in the general population,

> The public, all they hear is 'escaped prescribed fire.' **"Oh my gosh, the world's coming to an end!"** (FWS1.1)

When individuals have little experience with a phenomenon such as prescribed fire, they are likely to conflate readily available reports about fire-related events with accurate information about prescribed fire (Twidwell et al. 2015). Such reports can include wildfire events that are unrelated to properly administered prescribed burns, or sensationalized media coverage of rare escaped prescribed fires that account for less than 1% of all prescribed fires in the SGP (Weir et al. 2019). A Texas A&M AgriLife Extension employee described the difficulties of burning near relatively populated areas due to the media-driven negative cues that inform individual heuristics:

> The majority of the population of Texas does not understand what fire once did and what we're trying to do with prescribed fire as a tool today. **They only read the reports in the media that death and destruction took place and they're not going to change their mind.** (ALES1.2)

The employee cites public fear of prescribed fire as being fueled by media reports covering fire in general, much of which relates to wildfires, their resultant damage, and related fire-fighting efforts (Jacobson, Monroe, and Marynowski 2001). When approached by the Extension employee to discuss the use of prescribed fire, these individuals utilized heuristics with negative emotional tags that were created by coverage of events, notably wildfires, that were predominantly unrelated to prescribed fire. Another Extension employee commented on similar occurrences of heuristics based on systemic bias:

> … you hear a lot of negativity [about] fire. And when you drive into some of our towns, they have a cut-out of Smokey the Bear that [communicates to those passing by] the [wild] fire risk. **It makes people feel like there's not a lot of difference between a wildfire and a prescribed fire.** And you and I know they're wildly different. (ALES1.4)

This manner of heuristic application was not confined to people living in urban or peri-urban areas. A Prescribed Burn Association (PBA) member from rural Texas described the perspective of a neighbor who did not use prescribed fire due to experiences with poorly managed burn piles:

> [The] landowner [who] … is 88 and a half years old … has had ranch managers in the past [who] lit feed sacks on fire [and] … consequently burned about 500 acres. So, he is very averse to risk and doesn't like the risk aspect of [prescribed fire] … **that's how he shapes his feeling[s] about fire.** (PBA1.5)

As is evident in the preceding excerpts as well as Table 2, heuristics are used in decisions both for and against the implementation of prescribed fire (i.e., both scientifically supported and unsupported decisions). The table summarizes the likelihood that prescribed fire will be implemented given the decision-making process being used. While heuristic processes were documented twice as frequently (47%) as analytic processes (23%), the latter resulted in a three times greater likelihood of prescribed fire use. Importantly, when analytical process dominated in decision-making about prescribed fire, the likelihood of use of this management tool was 100%.

These findings confirm Hypothesis 2 that analytic decision-making processes lead to a greater likelihood of prescribed fire implementation than heuristic processes. Although not included in the hypotheses, dual-process approaches also warrant further investigation as they result in higher rates of fire use than heuristics alone.

Table 2. Outcomes of heuristic, analytic, dual, and indeterminate decision-making processes.

	Number	Percentage of decisions	Fire implementation	No fire implementation	Percentage utilizing fire
Heuristic	34	47%	11	23	32%
Analytic	17	23%	17	0	100%
Dual	20	27%	11	7	55%
Indeterminate	2	3%	0	2	0%
Total	73	100%	39	32	–

Provided sufficient quality data and ample time to decide, analytic processes are superior to heuristic processes for ensuring ecologically desirable outcomes of periodic fire in the SGP. These following landowners' descriptions of cost-benefit analyses illustrate the power of analytical decision-making:

I think it is probably the most effective tool, and especially when you **figure out cost per acre**. (PBA2.4)

Recognize that burning is risky, you just **weigh the risk versus the labor and reward**. (PLPC2.2)

In summary, the results support the contention that land management decisions are more frequently based on heuristic than analytic processes. These results also support the idea that analytical decision-making processes are more likely to lead to greater use of ecologically beneficial land management tools in the SGP, such as prescribed fire, than heuristic or dual decision-making processes. However, whether an individual has sufficient time and adequate access to scientifically sound data to make decisions analytically is uncertain. Landowners in the SGP who might use prescribed fire are faced with a multitude of daily decisions and the likelihood that each decision will occur under ideal conditions may be low.

Discussion and Conclusion

Implications of Heuristic Process Usage

As Pyne (2001, 25) notes, humanity's association with fire is no less than a "Faustian pact" which has offered our species tremendous evolutionary advantage at terrible potential cost. Fire is alternatively capable of raising us from our early hominid ancestors' existence and causing calamitous ruin with every ignition. Perhaps this marked duality of potential outcome is why prescribed fire provides such a unique perspective from which to examine decision-making. Whether due to its sheer elementality or its perceived catastrophic potential, fire facilitates analytical clarity into individual decision-making that is difficult to capture in other woody plant management practices, such as chemical or mechanical treatments. This perspective has revealed boundedly rational individual decision-making processes comprised of multiple methods of making decisions that are often used concurrently to inform one another (Kahneman 2011).

Our conceptualization of decisions regarding the use of prescribed fire documents the presence of heuristics processes alongside analytic and dual-process approaches in such decisions. This focus on heuristics is unique in this literature and provides insight into cognitive processes with application to more increased use of prescribed fire. However,

it is important to note theoretical alternatives or limitations to the study. The analytical framework focused primarily on the use of the affective heuristic, although in many instances there were likely other heuristic strategies at play such as recognition (e.g., having the personal experience). The instances of affect or recognition heuristics could be interpreted through a lens of self-efficacy (Bandura 1982), particularly explaining how past experiences lead to future implementation. Moreover, many of the instances could be measured as attitudes, beliefs, and perceived behavioral control suitable for the Theory of Planned Behavior (Ajzen 2002). These different theoretical lenses may all offer valuable interpretation, yet as this research demonstrates there is a strong face validity rationale for linking affect heuristics to prescribed fire use. This study is also limited by the inclusion of both interviewee actions and opinions as decisions regarding prescribed fire-related issues. Although further investigation is required, it is possible this heuristic tool influences opinions and actions differently.

Nationally, prescribed fire has been erroneously branded as a high-risk practice with the possibility and even likelihood of extreme negative consequences (Twidwell et al. 2015). Internationally, debates concerning the risks and benefits of prescribed fire in land management are ongoing in Australia (Altangerel and Kull 2013), South Africa (Bond and Archibald 2003), and Europe (Harper et al. 2018). While personal injury, loss of life, and catastrophic property damage are possible outcomes of escaped prescribed fire, unintended damages have occurred in less than 1% of burns in the US and are far less probable than positive outcomes (Weir et al. 2019). Additionally, many of the alternative chemical and mechanical brush management practices in use today have been shown to be more dangerous and costlier on a per use basis (Twidwell et al. 2015; Van Liew et al. 2012). Indeed, a fire practitioner is statistically more likely to be injured in a motor-vehicle accident on the way to the prescribed fire than by the fire itself (Twidwell et al. 2015).

It is likely that some of the discrepancy between perceived likely negative outcomes and statistically probable negative outcomes is due to the use of heuristic processes, which can lead to unsubstantiated conclusions about prescribed fire risks. This is based on the observation that the affective heuristic relies on emotional tags associated with memories of earlier fire-related reports or experiences. Prescribed fire implementation is often spuriously intermingled by the general public with wildfire (Twidwell et al. 2015) and can be erroneously labeled as an unsafe practice due to these emotional forces. One Oklahoman landowner described the way these emotions are formed:

> … [fire] is so guttural. When it really **hits the limbic system**, people are scared of it. (PLPL 2.2)

Decision-making models, such as *homo economicus*, that focus on utility maximization and analytic thought processes have historically failed to account for the more emotional or instinctive components of decision-making (Kahneman 2011). While heuristics with positive cues about prescribed fire can lead to fire's application, our study suggests that is more often the exception than the rule. When prescribed fire is categorized as a "high risk" land management practice as a result of heuristics based on a negative cue, anti-fire biases are more likely to occur. Our research suggests that these negative cues are frequently associated with wildfire rather than prescribed fire.

By identifying and acknowledging the use of heuristics and negative biases in prescribed fire decision-making, land management professionals can consider the implications for both how fire policies are formulated and the way the practice is discussed and taught. A more accurate depiction of how individuals decide to implement prescribed fire has significant implications in a number of contexts, which are discussed below along with possible courses of action that explicitly address the effect of heuristics on the use of prescribed fire.

1. *Long-term county burn bans*—In the public domain, elected and appointed officials also employ heuristics in their decision-making. This can be seen in county-level burn bans that are maintained for long periods even when prescribed fire can be used safely and most beneficially to counter woody plant encroachment (Weir 2011). Although procedures for implementing burn bans vary by county, these bans are typically instituted by a county commissioners court over which the county judge presides, and a county fire marshal is typically consulted for technical input before a burn ban is enacted (Texas A&M Forest Service 2019). However, a burn ban does not require a fire marshal's input for initial establishment and can be kept in place as long as the county judge or county commissioners wish. The occurrence of county burn bans that extend beyond ecological necessity and impede prescribed fire implementation are common in the SGP (Weir 2011; Twidwell et al. 2013). While likely well-intentioned, these authorities are often not prescribed fire experts and are prone to the use of scientifically unsupported negative heuristics to make decisions about the implementation of burn bans.

2. *Prescribed fire insurance policies*—Heuristics likely also play a role in insurance underwriting. The dearth of insurance carriers willing to supply adequate policies has been cited as a major impediment to the more widespread use of prescribed fire (Yoder and Blatner 2004). While insurance carriers use actuarial analyses to determine the risk associated with the provision of an insurance policy, underwriters also apply personal assessments to gauge the level of risk (Weir et al. 2019). In the case of prescribed fire, insurance underwriters typically have little personal experience with this land management tool, and it is likely they use similar heuristic processes as the general public when conducting personal assessments of risk. While this is largely undocumented, the highly cautious and underwritten value of most prescribed fire insurance policies (Yoder et al. 2003), in the face of overwhelming statistical evidence of prescribed fire's safety, suggests currently unexplored processes may be negatively influencing the issuance of prescribed fire-related policies.

3. *Outreach and education*—Prescribed fire outreach and education are also impacted by heuristics. A number of state and federal agencies as well as non-profit organizations run programs which provide technical information about prescribed fire and aim to connect with and educate the general public and private landowners about this land management tool (Taylor 2005). While technical aspects are essential components of prescribed fire education and outreach, they often fail to address the way people "feel" about fire in general, and prescribed

fire in particular. Programs that focus largely on dissemination of technical information often forgo a key element in the education process, which is the processing of new information and experiences at an emotional level. As is clear by the extent of heuristic use in the interview data, emotional processing of information occurs routinely. Therefore, to be most impactful, it is essential that people teaching about prescribed fire acknowledge and address the emotional side of learning (Wolfe 2006).

Paths Forward

The incorporation of heuristics into outreach and education programs has the potential to shift the perception and use of prescribed fire in a variety of contexts. To better engage individual landowners, county-level officials, and insurance underwriters, prescribed fire outreach and education programs should incorporate two additional components.

1. *Understanding individual fire experience*—The first component would emphasize understanding individual's personal broad experience with fire, including first-hand experiences with prescribed fire and wildfire as well as secondhand knowledge of both. This component would give an instructor a better understanding of how heuristics might influence an individual's decision-making. The quote from the ranch manager describing how the Hayman Fire in Colorado bypassed her family ranch is an illustrative example. For an individual using heuristics with negative cues about prescribed fire, identifying past experiences with fire might reveal the incident(s) responsible for the affective tag. Once identified, new experiences can be created to supplant the negative effects of those incidents and to create a more positive attitude to the use of prescribed fire and, ultimately, more widespread use of this beneficial rangeland management tool. This might be as simple as having an individual who is generally fearful of fire but has no first-hand experience accompanying a burn practitioner on a prescribed burn. A Natural Resource Conservation Service employee from Oklahoma commented on the effect of direct engagement of non-practitioners:

> It's just really helped to get them out to observe a prescribed fire. They really **don't understand it until they witness one** … how it can act … It's just a learning process to observe. (NRCS2.3)

2. *Addressing multiple process usage*—The second component would emphasize openly addressing the multiple processes individuals use to make decisions about prescribed fire. This effort would address two issues, the first being that many people seem to be unaware of their use of heuristics, especially in situations with perceived high risks. Openly addressing the fact that people regularly use these mental shortcuts to make quick decisions may be a revelation to many. Secondly, some demographic characteristics (e.g., gender, age, and education) may be correlated with negative responses to the idea that decisions may be partially emotionally

based (Beyer and Bowden 1997). For example, younger, more-educated men may be less inclined than women and older individuals, to accept the idea that their decisions are based, at least in part, on emotional factors. Such negative responses to the idea that emotions impact decision-making processes might make it more difficult for certain people to accept the concept of heuristics. Addressing this directly and with careful language could mitigate such negative responses to this idea and allow prescribed fire decision-making to be better understood by people who could affect the broader use of this important land management tool.

Ultimately, the benefit of a more realistic depiction of prescribed fire decision-making is the application of fire on a landscape scale in a manner that positively impacts the delivery of many valuable ecosystem services in the SGP as well as other fire-driven ecosystems. Were this to be achieved, it is possible that the degradation of many of these services—forage production, wildlife habitat provision, wildfire threat mitigation, carbon sequestration, etc.—might be reversed. However, more research on the diversity of heuristic effects on decision-making processes is necessary. Further qualitative work might provide more detailed examples of heuristic usage on an individual scale, illuminating the impact of heuristics on prescribed fire in greater detail. Quantitative studies capable of identifying the strength of linkages between individual's emotions, heuristic usage, and fire implementation might provide more concrete evidence as to the influence of these types of processes on prescribed fire use. Both qualitative and quantitative assessment of fire-related heuristics are necessary to better understand barriers to and opportunities for the use of prescribed fire in the SGP and more broadly in other fire-driven ecosystems.

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