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The role of prescribed burn associations in the application of prescribed fires in rangeland ecosystems

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ABSTRACT

Risk and liability concerns regarding fire affect people's attitudes toward fire and have led to human-induced alterations of fire regimes. This has, in turn, contributed to brush encroachment and degradation of many grasslands and savannas. Efforts to successfully restore such degraded ecosystems at the landscape scale in regions of the United States with high proportions of private lands require the reintroduction of fire. Prescribed Burn Associations (PBA) provide training, equipment, and labor to apply fire safely, facilitating the application of this rangeland management tool and thereby reducing the associated risk. PBAs help build networks and social capital among landowners who are interested in using fire. They can also change attitudes toward fire and enhance the social acceptability of using prescribed fire as a management practice. PBAs are an effective mechanism for promoting the widespread use of prescribed fire to restore and maintain the biophysical integrity of grasslands and savannas at the landscape scale. We report findings of a project aimed at determining the human dimensions of using prescribed fire to control woody plant encroachment in three different eco-regions of Texas. Specifically, we examine membership in PBAs as it relates to land manager decisions regarding the use of prescribed fire. Perceived risk has previously been identified as a key factor inhibiting the use of prescribed fire by landowners. Our results show that perceived constraints, due to lack of skill, knowledge, and access to equipment and membership in a PBAs are more important factors than risk perceptions in affecting landowner decisions about the use of fire. This emphasizes the potential for PBAs to reduce risk perceptions regarding the application of prescribed fire and, therefore, their importance for restoring brush-encroached grasslands and savannas.

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1. Introduction

The combined effects of increasing population densities, excluding fire, extending fire intervals, overgrazing, and drought have produced an increase in woody plant species, thereby altering the grass dominated nature of grassland and savanna ecosystems (Archer, 1994; Archer et al., 1995; Higgins et al., 2000; Langevelde et al., 2003). Fire suppression and the resulting increase of woody species generally result in a series of associated cascading biophysical effects, including decline in the quality of wildlife habitat, reduced herbaceous biomass production, reduced surface water infiltration, increased surface water runoff, increased soil erosion, and altered biogeochemical cycles (Brown and Rollins, 2005; Holechek and Hess, 1994; Martin and Morton, 1993; Bhark and Small, 2003; Archer, 2001; Backer et al., 2004; Davenport et al., 1998; Reid et al., 1999). These deleterious effects may extend across spatial boundaries and influence not only local areas but also watersheds and whole regions.

Although the ecological thresholds for restoring these fire-adapted ecosystems back to their original state are better understood than in the past, the key hurdle to reintroducing historical fire regimes at landscape scales is a social one (Dombeck et al., 2004). Prescribed fires have not been used as a restoration tool to the extent needed, mostly because of safety and legal liability concerns (Kreuter et al., 2008). These constraints increase as wildlands become encroached by urbanization (Smeins et al., 2005). Perceptions of risk are not only affected by education and experience but also by individual and societal values (Slovic, 1987; McCaffrey, 2008). From an individual's standpoint, motivation and perceived self-efficacy are important determinants of behavior (Grothmann

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and Patt, 2005). Landowners rarely have sufficient labor, equipment, and insurance to carry out prescribed burns on their own, which potentially increases the perception that applying fire is risky. In order to achieve landscape-scale fire-driven ecosystem changes across boundaries, individual constraints to applying prescribed burns must be understood and overcome (Toledo et al., 2012).

Cooperation in addressing landscape-scale environmental problems combines individual efforts to achieve an outcome that exceeds the sum of individual efforts (Ostrom, 1990; Yaffee, 1999). Prescribed burn associations (PBAs) are a promising tool to address individual constraints and achieve landscape-level outcomes (Toledo et al., 2012, 2013; Taylor, 2005). PBAs are non-profit entities started by, and composed of volunteers who seek to collectively and cooperatively restore or maintain rangelands through the application of prescribed fire (Taylor, 2005; Kreuter et al., 2008). Members are mostly comprised of landowners with properties that are sufficiently large to apply fire but other private citizens and state and federal employees, may be also be members (Taylor, 2005). PBAs reduce the risk of applying fire through the collaborative efforts of neighboring landowners, and in some cases also the provision of supplemental liability insurance for their members. As institutions PBAs can also generate trust at broader scales. For example, owing to their demonstrated safety record, some PBAs have been permitted to burn during burn bans, when fires often produce their greatest restorative effect (Twidwell et al., 2012).

Social exchange theory posits that a person's actions are based on the actions of others and that exchanges between people within a group build over time and lead to the development of mutually and rewarding relationships (Cropanzano and Mitchell, 2005). PBAs facilitate cross-boundary adoption of fire through the social networks and social capital generated by the repeated interactions with other landowners (Cropanzano and Mitchell, 2005). Social capital refers to the expected benefits, such as trust, reciprocity and community involvement, derived from interactions and cooperation between individuals (Ostrom, 1990; Cropanzano and Mitchell, 2005; Wagner et al., 2006). According to social exchange theory, PBA membership can lead to the emergence of relationships and a shared identity among members that fosters pride in the group and trust among its members, leading individuals to behave in ways that conform to group rules and norms (Van Vugt and Hart, 2004; Cropanzano and Mitchell, 2005). These social norms (informal rules that guide behavior) are a primary motivator in the adoption of behavior (Cialdini et al., 2006) and can be effectively used as a tool to promote changes in behavior (Biel and Thogersen, 2007). Further, collaborative groups have become increasingly popular vehicles for promoting natural resource management because their governance structure is often based on a participatory, democratic approach that focuses on shared ownership and responsibility (Wondolleck and Yaffee, 2000) and provides peer-to-peer learning opportunities (Kreuter et al., 2008).

The objectives of this study were to assess landowner perspectives regarding the use of prescribed fire and evaluate the role of PBAs in promoting the adoption of prescribed fire at the landscape scale. We hypothesize that landowner decisions to use prescribed fire as a woody plant management tool are negatively related to risk aversion, perceived lack of skill and knowledge, and access to labor and equipment to apply fire safely, and are positively related to PBA membership.

2. Methods

2.1. Study sites

The study was conducted in 12 counties in Texas, consisting of clusters of four counties in each of three ecoregions. The ecoregions included the Rolling Plains (North), the Edwards Plateau (central), and the South Texas Coastal Plains (South), all of which are located within the Southern Plains of the USA. Study areas were selected to represent a north–south ecological gradient with vegetation transitioning from midgrass prairie/honey mesquite (*Prosopis glandulosa*) dominated savanna in the Rolling Plains; to Juniper (*Juniperus asheii*) and oak (*Quercus* sp.) dominated woodlands in the Edwards Plateau; and to coastal prairie and mixed brush in the South Texas Coastal Plains. All three regions exhibit varying degrees of brush encroachment, primarily by honey mesquite and prickly pear cactus (*Opuntia* sp.). The Edwards Plateau is also encroached by Ashe juniper and the South Texas Coastal Plains by Huisache (*Acasia farnesiana*).

2.2. Mail survey

A self-administered questionnaire was mailed to 1187 landowners to gather information regarding landowner attitudes and perceptions toward the use of prescribed fire as a rangeland management and restoration tool. We selected 100 landowners with 20 or more hectares of land in each of the 12 counties for the study. The 100 landowners in each county included all landowners who were members of a PBA (ranging from 0 to 33) and the rest of the landowners were randomly selected from the county tax mailing list. Although the PBA members were not subsampled, because the number of members in each county was less than 100, the surveyed group nevertheless represents a regionally stratified sample of all members of PBAs in the region.

The mail survey was initiated in June 2008 using a slightly modified multi-phased mailing procedure adapted from Dillman (2000). We used five mailings that included a pre-survey notification letter on day 1; a questionnaire with cover letter and a self-addressed postage paid envelope on day 7; a reminder postcard on day 14, a replacement questionnaire with cover letter and another self-addressed postage paid envelope on day 28; and a final reminder/thank you postcard on day 40. In addition to the mail survey, a non-response bias survey was conducted 6 months after the last mailing of the initial survey. This was accomplished by randomly selecting 50% of the non-respondents and sending them a short questionnaire that included a few key questions from the initial questionnaire and that asked them to indicate why they had not participated in the survey.

2.3. Data collection

Data were obtained mainly through the use of a 7 point Likert-type scale in which subjects were asked to express agreement or disagreement with specific statements. Each degree of agreement was assigned a value (1 = strongly disagree … 4 = neutral …7 = strongly agree).

To address our hypothesis, we conceptualized landowners' decisions to perform a prescribed fire to be influenced by attitudes toward prescribed fire, perception of the risk of using fire relative to that of using other woody plant management options, perceived constraints of applying fire including lack of skill, labor, knowledge and equipment, and whether or not they are a member of a PBA. Questions used to test this hypothesis included: "Have you ever performed a prescribed burn on your land?" and, "Are you a member of a prescribed burn association?" We also asked landowners to express their level of agreement or disagreement with the following statements: I consider the use of prescribed burning to be a beneficial tool for restoring rangelands; I agree in principle with the idea of using prescribed burning on my land when needed; I am in favor of applying prescribed burning on my land whenever it is needed and there is sufficient fuel to burn;

Prescribed burning has potentially greater risk than other woody plant control methods; I am concerned about using prescribed burning because I lack knowledge and/or experience about fire safety; and, I am concerned about applying prescribed burning because of lack of labor and/or equipment needed. In addition, information about levels of trust, reciprocity, and collective action among PBA members was used to explain the effects of PBAs on perceived risks. For this, two sets of measurable variables based on the Likert-type scale were used: a) attitudes toward prescribed fire; and b) level of trust, reciprocity, and collective action among members of PBAs in Texas.

Single scale indices for two latent factors were created; latent factors are factors that are not observed directly but are mathematically inferred from the data (Kaplan, 2000). The two latent factors are *attitude* and *perceived constraints*. *Attitude* refers to the tendencies people have to favor or not a specific entity (Ajzen and Fishbein, 2000). For the purpose of this study, attitude is related to landowners' favorable disposition to prescribed fire. *Perceived constraints* refer to concerns landowners have due to lack of knowledge and/or experience about fire safety and landowner concerns about the lack of labor and equipment needed to safely implement a prescribed fire. Cronbach's alpha was used to test reliability of the attitude and perceived constraints indices that were calculated using principle components factor analysis. Cronbach's alpha value for *attitude* and *perceived constraints* was 0.92 and 0.82, respectively, suggesting these latent factors are robust indices.

2.4. Data analysis

Survey data regarding actual use of prescribed fire by members and non-members of PBAs were used to determine the influence of PBAs in promoting the use fire as a management tool at a landscape scale. Initially, the data were analyzed descriptively using independent sample *t*-tests for normally distributed data, Mann–Whitney tests for non-normally distributed data, and Chi-Square tests for binary categorical variables. We used binary logistic regression models to examine the relationship between the application of a prescribed burn on one's land (1 = Yes, 0 = No) to risk perception, perceived lack of skill, knowledge, access to labor and equipment (perceived constraints), and PBA membership. We estimated four models, one for each ecoregion and a pooled model. We report both the log odds and odds ratios coefficients for the logistic regression. Odds ratios are a measure of effect size that describes the strength of association between two binary values and can be used to calculate the percent change: (Odds Ratio − 1) *100% (Vittinghoff et al., 2005).

3. Results

3.1. Survey response rates and bias

From the 1187 survey participants, we received 585 useable responses (129 PBA-members and 456 non-members), representing an overall response rate of 49%. For the non-response bias survey we received an 11% response from the original non-respondents. Comparison between the responses to the original questionnaire and the non-response bias questionnaire detected no statistically significant differences suggesting that the respondent group represented an unbiased subset of the survey population.

3.2. Relationship of PBA membership with attitude, fire use and risk perception

Of the 585 responses received, 129 respondents were members of PBAs and 187 had performed burns on their lands. We received the most responses from landowners in the Edwards Plateau ecoregion where the first PBA was established (Table 1). The Edwards Plateau Prescribed Burn Association had the largest number of PBA members and represented the largest group of landowners who had applied fire in the study group.

Most (86%) survey respondents slightly agreed to strongly agreed with the use of prescribed fire and most (89%) slightly agreed to strongly agreed that prescribed fire is beneficial land management tool that they would use. There are, however, significant differences between PBA member and non-member attitudes and perceptions regarding fire and actual application of prescribed fire (Table 2). In general, compared to non-members, PBA members were more favorably disposed to prescribed burning and favored it over other brush control methods. In addition, more PBA members than non-members had applied prescribed fires on their land. Results also show that attitudes toward the use of fire in general correlated with the survey respondents' risk perceptions ($r = 0.669$; $P < 0.001$). Due to the high correlation between attitudes and risk perceptions, we excluded attitudes from the regression analyses to avoid multicollinearity issues.

3.3. Combined effects on the application of prescribed burning

Logistic regression analyses were conducted for each of the three ecoregions and for the pooled data to explore the overall influence of three factors (perceived risk, perceived constraints and PBA membership) on the use of prescribed fire across the study area. The regional logistic regression analyses (Table 3) suggest that controlling for other factors, risk perception was significantly related to landowner decisions to apply prescribed fire on their land in the Rolling Plains but this relationship was not present for the other two sites. In contrast, perceived constraints to applying fire (lack of knowledge, experience, labor and equipment) were related to the application of fire across all three regions, controlling for perceived risk and PBA membership, the odds of a landowner having applied a prescribed burn on their land decrease by 51% for each unit increase in perceived constraints.

PBA membership was a significant explanatory variable for the application of prescribed fire at all sites. In the Rolling Plains and Edwards Plateau, the odds of PBA members having performed a burn compared non-members were as much as10 times higher, while in the Coastal Plains PBA members were almost 6 times more likely to perform a burn than non-members (Table 3).

When the data were pooled for all three regions, all factors were found to be statistically significant explanatory variables for burning behavior by landowners (Table 4). In this overall assessment, PBA members were 8 times more likely to perform a prescribed fire than non-members, and controlling for other factors, the odds of a landowner having applied a prescribed burn on their land decrease by 39% for each unit increase in perceived constraints. When all ecoregions were pooled together perceived risk was significantly related to having applied prescribed fire. Interestingly though, the effects of risk in the pooled results suggest that

Table 1
Total number of respondents, number of respondents who were a PBA member and respondents who had performed at least one prescribed fire on their land, by ecoregion.

Ecoregion	Respondents	PBA Members	Performed burn	% Burners with PBA membership
	N (%)	*N* (%)	*N* (%)	
Rolling Plains	180 (31)	27 (21)	57 (31)	23
Edwards Plateau	234 (40)	93 (72)	88 (47)	66
Coastal Plains	171 (29)	9 (7)	42 (22)	7

Table 2
PBA member versus non-member response values and differences for attitudes toward prescribed fire and actual fire application. Attitude values are based on a 7-point scale (1 = strongly disagree … 4 = neutral … 7 is strongly agree).

Respondent characteristics	PBA members	Non-members	Difference	*P*-value
Are in favor of prescribed burning	6.7	5.5	1.2	<0.0001
Favor burning over other brush control methods	5.8	5.0	0.8	<0.0001
Have performed a prescribed burn on their land	53%	47%	6%	<0.0001

all else being equal, the odds of landowners having applied a prescribed burn increase by 19% for each unit increase in perceived risk, suggesting that burning is happening despite risk concerns.

The low or insignificant effects of risk across regions and the high effects of membership in a PBA suggest that the level of perceived risk of landowners is potentially moderated by membership in a PBA. PBAs offer access to a shared pool of risk-reducing knowledge and resources and, in addition, they may offer liability insurance for their members.

To further evaluate the influence of PBAs on landowner willingness to burn their land, we evaluated factors related to social capital, including trust, reciprocity and adherence to social norms for PBA members. Members generally trust each other and would help and loan equipment to each other regardless of whether they were related or not (Table 5). Additionally, PBAs help landowners reach land management objectives and, most importantly, PBA members generally follow guidelines and recommendations set by their PBA.

4. Discussion

The reintroduction of fire at the landscape scale is needed to restore degraded grassland and savanna ecosystems, and to reduce fuel load accumulations. The challenge to accomplishing this is resistance by landowners to intentionally ignite fire on their land. We empirically demonstrate that PBAs play a critical role in addressing this challenge. PBAs engender trust, reciprocity and cooperation amongst members, which allow them to adopt and promote fire as a safe, effective and economically efficient rangeland management and restoration tool.

Trust is an important factor that can help identify outcomes of social exchanges (Dirks and Ferrin, 2002). Our data show that trust among members of PBAs is moderately high and, given the short time these PBAs have been in operation, may increase over time as relationships among PBA members strengthen. An important tenet in social exchange theory that applies to PBAs is that rules and norms of exchange allow relationships to evolve into trusting, loyal, and mutual commitments over time (Emerson, 1976; Cropanzano and Mitchell, 2005). PBA members are bound by a set of rules of exchange that determine how equipment and labor are distributed. For example, members of the Edwards Plateau Prescribed Burn Association can only apply prescribed fire on their land using PBA resources after they assist with three burns on other member's properties. This rule results in mutually beneficial reciprocity arrangements among members. Additionally, this interdependence encourages cooperation among group members (Molm, 1994), which can potentially reduce liabilities. PBAs can significantly reduce landowners' risks of an intentionally ignited fire burning out of control by sharing experience, labor and equipment. This ultimately increases the potential capacity for using prescribed fire as a rangeland improvement tool at landscape, watershed and even regional scales.

Our study found that the actual use of fire was either not or marginally associated with risk perceptions. Instead, application of fire was related to perceived constraints to apply it safely (lack of knowledge, experience, labor and equipment) (see also Toledo et al., 2013). This contrasts with perceptions held by those in charge of fire management who perceive risk aversion as being a

Table 3
Logistic regressions demonstrating the relationship between perceived risk, perceived constraints, and PBA membership, on landowner willingness to apply a prescribed fire in three ecoregions (B = log (odds) coefficient; SE = standard error; Wald χ^2 = Wald Chi-Square; df = degrees of freedom; OR = Odds Ratio).

	B	S.E.	Wald χ^2	df	*P* value	OR
Rolling Plains (n = 154)						
Perceived risk	0.307	0.143	4.577	1	0.032	1.359
Perceived constraints	−0.720	0.139	26.966	1	0.000	0.487
Member of a PBA (no = 0; yes = 1)	2.387	0.650	13.486	1	0.000	10.882
Constant	−0.068	0.773	0.008	1	0.930	0.934
Model χ^2 = 77.056; Nagelkerke R^2 = 0.535; df = 3; *P* value < 0.0001						
Edwards Plateau (n = 202)						
Perceived risk	0.180	0.108	2.810	1	0.094	1.198
Perceived constraints	−0.420	0.104	16.366	1	0.000	0.657
Member of a PBA (no = 0; yes = 1)	2.295	0.368	38.812	1	0.000	9.921
Constant	−0.697	0.616	1.278	1	0.258	0.498
Model χ^2 = 91.249; Nagelkerke R^2 = 0.475;df = 3; *P* value < 0.0001						
Coastal Plains (n = 139)						
Perceived risk	0.038	0.130	0.087	1	0.768	1.039
Perceived constraints	−0.424	0.121	12.362	1	0.000	0.654
Member of a PBA (no = 0; yes = 1)	1.854	0.876	4.479	1	0.034	6.382
Constant	0.503	0.776	0.421	1	0.516	1.654
Model χ^2 = 24.767; Nagelkerke R^2 = 0.228; df = 3; *P* value < 0.0001						

Table 4
Logistic regression demonstrating the influence of perceived risk, perceived constraints in applying fire (lack of knowledge, experience, labor and equipment), and PBA membership, on landowner willingness to apply a prescribed fire across all three ecoregions (B = log (odds) coefficient; SE = standard error; Wald χ^2 = Wald Chi-Square; df = degrees of freedom; OR = Odds Ratios).

All ecoregions combined (n = 495)	*B*	S.E.	Wald χ^2	df	*P* value	OR
Perceived risk	0.176	0.071	6.110	1	0.013	1.192
Perceived constraints	−0.498	0.066	56.255	1	0.000	0.608
Member of a PBA (no = 0; yes = 1)	2.089	0.269	60.404	1	0.000	8.078
Constant	−0.123	0.404	0.093	1	0.760	0.884

Model χ^2 = 193.331; Nagelkerke R^2 = 0.432; df = 3; *P* value < 0.0001.

Table5
Levels of trust, reciprocity and collective action among prescribed burn association members in Texas. Values based on a Likert-type scale were 1 is strongly disagree and 7 is strongly agree.

Statement	Mean	SD
I trust members of my burn association.	5.21	1.52
I would spend time helping non-kin association members.	5.33	1.57
I would loan equipment to non-kin association members.	5.24	1.62
Being a member of a prescribed burn association will help me achieve my land management objectives.	5.26	1.69
If my association urged its members to adopt certain conservation practices, most would likely comply.	5.11	1.50

primary inhibitor for the application of fires (Pyke et al., 2010). This difference may be related to the way in which we measured risk perception. The actual statement, "Prescribed burning has potentially greater risk than other woody plant control methods", measures the relative risk of burning. Thus, our measure included an element of knowledge about the risk of different management practices instead of the risk of igniting fire *per se*. However, this measurement approach seems reasonable given the fact that landowners likely evaluate each land management practice based on risk and then order them accordingly.

Fischer (2011) found that people who perceived greater risk but who viewed risk as controllable were more likely to act than those who perceived risk to be uncontrollable. This suggests that landowners' level of perceived risk (igniting fire) could be reduced and their willingness to act (apply fire) could be increased by providing access to training, skilled labor and equipment on burn days. These are primary functions of PBAs. Additionally, Slovic et al. (1982) show how exposing people to a positive message about a new technology can change their beliefs about risks toward that technology. As prescribed fire becomes increasingly adopted as a land management tool, more landowners are being exposed to its use and its positive effects. While some prescribed fires have burned beyond their target areas with serious consequences, most fires produce positive effects that far outweigh the risks of ignition, which can potentially change people's beliefs about prescribed fire.

Our data show that PBA members have more positive attitudes toward fires than non-members. Although we can't say whether positive attitudes toward fire are developed because of PBA membership, or whether landowners with positive attitudes are more likely to join PBAs, this finding in combination with theory (Cropanzano and Mitchell, 2005) is encouraging. For example, PBA membership may help promote the use of fire by its effect on subjective norms regarding fire. Subjective norms are perceptions that others want us to engage in or avoid certain behaviors; they influence our intention to engage in particular behaviors and, therefore, they are strong motivators (Ajzen and Fishbein, 2005). In the natural resources field, subjective norms have been used to identify, plan, and communicate management decisions because of their importance in determining a person's intention to participate in a certain behavior (Ajzen and Fishbein, 2000; Kneeshaw et al., 2004). PBAs have been shown to increase social support by building and strengthening landowner networks and trust among members, changing attitudes toward prescribed fire and enhancing the social acceptability of prescribed fire as a management practice (Toledo et al., 2013). Another advantage of PBAs is that the cross-scale coordination and planning of prescribed fire reduce habitat fragmentation that has large-scale impacts on the environment.

As biophysical and social conditions change, landowners need to learn how to continually adapt to new conditions. PBAs provide the necessary network for landowners to respond to changing biophysical and social conditions in a more coordinated manner through the broad adoption of management practices, such as the use of prescribed fire. Such coordinated actions have the potential for positive large-scale environmental change.

5. Conclusions

Long-term fire suppression has contributed to the spread of woodlands and increases in moribund forests (Archer, 1994; Archer et al., 1995; Higgins et al., 2000; Langevelde et al., 2003). Collectively, this has led to fuel load increases and more severe and frequent wildfires in many rangeland and forest ecosystems. Even though prescribed fires will not eliminate the occurrence of wildfire, they can decrease the risk of catastrophic wildfire by reducing fuel loads and they can help land managers to restore, maintain or improve the health of fire adapted ecosystems, such as grasslands and savannas. This study reveals that access to skilled labor, knowledge and firefighting equipment can increase the application of prescribed fires by landowners in Texas. PBAs have facilitated access by landowners to these three resources, which are critical for the safe application of prescribed fire (Taylor, 2005). The apparent importance of PBAs for enhancing the use of prescribed fire on private land is important information for extension and government agencies that are tasked with the conservation and improvement of natural resources. If their objective is to restore and protect the integrity and vigor of grasslands and savanna ecosystems in the face of changing climatic conditions, facilitating the periodic application of prescribed fire across the landscape is critical. To achieve this on private land, educating people about the advantages of prescribed fire through PBA membership and promoting membership to these associations is a good way to empower landowners to apply prescribed fire safely and willingly.

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