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Research Article

Embracing Complexity and Context to Improve Science Communication

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ABSTRACT Members of the public play a primary role in successful implementation of wildlife management plans, making communication between scientists and the public a vital component of wildlife management. Although there is substantial public interest in the health of ungulate populations, stakeholder perspectives can vary widely, rendering a single approach to communication ineffective. To improve science communication, we characterized perspectives regarding issues negatively affecting mule deer (*Odocoileus hemionus*) in Wyoming, USA. We used Q methodology, a mixed quantitative-qualitative approach where participants ranked a series of statements followed by semi-structured interviews, to identify shared perspectives. We interviewed individuals ($n = 37$) representing prominent stakeholder groups (e.g., ranchers, hunters, conservation non-profits) in Wyoming. We identified 3 perspectives (52% of variance explained) that captured shared views regarding what factors are negatively affecting mule deer: bottom-up ($n = 17$ participants; 26% variance), human contributions ($n = 9$; 14% variance), and top-down ($n = 8$; 12% variance) perspectives. Most participants shared the idea that mule deer are being negatively affected, but participants diverged in views as to the primary issues. Perspectives ranged from being focused on bottom-up factors (e.g., habitat fragmentation, condition of winter ranges) to top-down factors (e.g., predation, disease) to factors focused on human contributions (e.g., human activity, public and political interests). Based on how participants diverged in perspectives and their interest in mule deer management, we discuss opportunities for scientists to improve communication by incorporating ecological complexity and nuance, moving towards a 2-way dialogue of communication, and sharing their own first-hand experiences in future communications with stakeholders. © 2021 The Authors. *The Journal of Wildlife Management* published by Wiley Periodicals LLC on behalf of The Wildlife Society.

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The success of any proposed action in wildlife management is determined largely by whether it resonates with and is supported by the public, regardless of the biological validity or feasibility of a given recommendation (Reed 2008, Teel and Manfredo 2010, Wolf and Moser 2011, Organ et al. 2012). Therefore, communicating with the public about issues that affect wildlife populations and any potential management action is an important component of wildlife management (Decker et al. 2012, Phillis et al. 2013). From a social media post meant to quickly communicate a scientific finding to sharing the state of scientific research in collaborative processes, biologists in many wildlife agencies, research groups, and non-profits increasingly are communicating scientific findings with non-scientific audiences to bolster support and engagement in wildlife management (Webler and Tuler 2006, Reed 2008). The groups that scientists are communicating with, however, rarely are homogeneous. In much of the United States, wildlife is managed at the intersection of hunting, recreation, wildlife viewing, agriculture, and energy development. Many of these groups have different—and, at times, competing—values, perspectives, and interests (Decker et al. 2012, Manfredo et al. 2018). Given that communication strategies are more successful when they are tailored to a specific audience (Leggette and Redwine 2017), successful communication strategies require that scientists have an in-depth knowledge of the groups they are communicating with; however, this knowledge and the tailored communication that can follow are often lacking (Varner 2014).

Tailoring messages to a given audience is important to successful communication in large part because of the ways that we incorporate new information into existing schemas. Although scientists often communicate under the assumption that people will change their minds with enough information (i.e., the deficit model of communication), people do not simply change their ideas and behaviors when given

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new information (Simis et al. 2016). Instead, according to the theory of reasoned behavior or cognitive hierarchy theory, new information first is filtered through a complex web of existing values, attitudes, and beliefs (Aipanjiguly et al. 2003, Barney et al. 2005, Manfredo et al. 2018, Miller et al. 2018). For example, how citizens valued wildlife shaped how receptive they were to different types of messages about safety around bears (*Ursus* spp.), which prompted recommendations for tailoring messages differently depending upon the target audience (Miller et al. 2018). The complex filter through which information is processed in the human mind demands that science communicators know their audiences well, including—but not limited to—possessing a deep understanding of audience perspectives, knowledge base, and values (Li et al. 2010, Fischhoff 2013, Cooke et al. 2017, Wilson et al. 2017). Further, a single approach to communication often will be ineffective because multiple worldviews will almost certainly be present in any situation involving wildlife (Manfredo et al. 2018). Despite the importance of tailoring messages, scientists tend to prioritize defending science or educating the public much more than customizing their communications to the audience (Dudo and Besley 2016) and otherwise fail to strategically approach communication (Kidd et al. 2019). Identifying perspectives that stakeholders possess and identifying possible ways to tailor messages in light of those perspectives should be integral components of any science communication strategy, but these steps are often overlooked (Fischhoff 2013).

Ungulates hold strong recreational, cultural, and economic importance across the United States and are popular focal points for science communication efforts. For example, the >300,000 mule deer (*Odocoileus hemionus*) distributed across Wyoming, USA, provide residents and non-residents with opportunities for recreation in the form of hunting, with over 48,000 hunters in 2020 alone (Mule Deer Working Group 2020). Mule deer in Wyoming have declined since the 1990s, and populations largely have been below the statewide objectives for population size, which have ranged from 565,000 to 476,000 mule deer across the state, since the early 2000s (Mule Deer Working Group 2020). Wyoming voters considered conservation issues such as the decline in populations of big game animals to be at least as serious as dependence on foreign oil and lack of jobs (Freedman and Korfanta 2014). Multiple entities, including non-profit organizations (NGOs), research groups at the University of Wyoming, the state wildlife agency, and statewide newspapers frequently discuss and highlight the status of mule deer populations and what might be affecting them. Further, the state wildlife agency has embarked on multiple collaborative processes with the public to involve stakeholders in decisions related to mule deer management (Mule Deer Working Group 2015).

Stakeholders interested in ungulates come to the table with a diversity of perspectives, which calls for carefully tailored science communication to ensure that the messages are received and received as intended. Stakeholders with interests ranging from wildlife watching to hunting to energy development are interested in the fate of mule deer and the landscapes they inhabit, and the engagement of all stakeholders is important given our current structure of wildlife being held in the public trust in the United States (Organ et al. 2012). Mule deer live in and move across landscapes that cross land ownership type and jurisdictional boundaries, which can present additional challenges for their management and subsequent science communication efforts (Middleton et al. 2019). In Wyoming, as with other states that are home to mule deer, land-use change, climate change, vehicle collisions, and predators are a few of the concerns that may negatively affect mule deer in certain contexts (Forrester and Wittmer 2013, Sawyer et al. 2016, Dwinnell et al. 2019). Because many different factors affect mule deer populations and stakeholders may hold diverse views regarding which factors are most important, a uniform approach to communication likely will be ineffective. At this time, however, wildlife scientists have done little research to tailor science communication regarding ungulates (i.e., identifying perspectives among stakeholders), instead focusing many human dimensions efforts on topics such as hunter satisfaction, motivation, or preference (Black et al. 2018, Serenari et al. 2019) and developing collaborative processes (Raik et al. 2005).

To improve communication with members of the public surrounding mule deer management, we characterized and described stakeholder perspectives concerning what they thought negatively affected mule deer. We further identified elements of viewpoints that were either points of consensus or served to distinguish perspectives, and we evaluated whether these consensus or distinguishing perspectives varied by wildlife value orientation.

STUDY AREA

Mule deer are distributed throughout Wyoming, in ecosystems including shortgrass prairie, mountain shrublands, conifer forests, and alpine tundra (Buskirk 2016). As of 2019, there were an estimated 343,300 mule deer throughout Wyoming, which is well below the current statewide population objective (476,600 mule deer; Mule Deer Working Group 2020). Wyoming has 578,759 residents, with a density of 2.2 residents/km^2 (United States Census Bureau 2021). The Wyoming Game and Fish Department manages mule deer hunting, primarily of males, throughout the state. Forty-eight percent of Wyoming's land is owned by the federal government, 43% is owned privately, and the remaining land is owned by the state and Wind River Reservation (Hamerlinck et al. 2013). Land use throughout the state includes agriculture, residential, commercial, industrial, and recreational (Hamerlinck et al. 2013). Average elevation was 2,000 m, and dominant vegetation types included conifer forests (Ponderosa pine [*Pinus ponderosa*], lodgepole pine [*Pinus contorta*] forests, Engelmann spruce [*Picea engelmannii*]), alpine tundra, sagebrush (*Artemisia* spp.) shrublands, and grasslands (Knight et al. 2014). Predators of mule deer in Wyoming included mountain lions (*Puma concolor*),

coyotes (*Canis latrans*), bobcats (*Lynx rufus*), black bears (*Ursus americanus*), and grizzly bears (*Ursus arctos*).

METHODS

Q Methodology Design and Implementation

We characterized stakeholder perspectives regarding factors negatively affecting mule deer in Wyoming using Q methodology. Q methodology is a discourse analysis approach that combines quantitative and qualitative techniques to identify shared perspectives across individuals (Brown 1980, Watts and Stenner 2005). Q-method approaches have a variety of applications to wildlife (Zabala et al. 2018): the method can be used to identify stakeholder groups (Vaas et al. 2019) and as a science communication tool (Gauttier 2019), in addition to the traditional role of identifying perspectives (Mattson et al. 2006, Peters and Ward 2017). In a Q-method study, participants are asked to rank a series of provided elements in order of importance in relation to other elements (Brown 1980, Watts and Stenner 2005). Doing so helps to illuminate how the participant constructs viewpoints. The ranking exercise (i.e., Q sort) often is followed by an interview where the participant can explain in detail what influenced their ranking decision. The researcher then uses the verbal explanation in combination with the ranking exercise to identify similarities in perspectives across participants and draw out the elements that make up perspectives. The numerical prevalence of perspectives among participants is not generalizable to the broader population but instead represents what concepts are important in discourses in a broader population.

We followed typical approaches in Q methodology to develop the concourse, select statements, and identify participants (Watts and Stenner 2005, Zabala et al. 2018). We developed the concourse (i.e., the broad pool of possible elements) by searching through local and statewide newspaper articles, comments and responses to newspaper articles, discussions on relevant forums, and Wyoming Game and Fish Department public meeting notes for a range of opinions concerning mule deer management in Wyoming from 2009–2019 (Peters and Ward 2017). We selected statements that were mentioned more than twice and spanned the range of potential issues that could be affecting mule deer (e.g., habitat conditions, predator pressures, human influence). The final Q sample consisted of 24 statements (Table 1). Although our Q sample was smaller than the typical range of statements (35–80 statements; Watts and Stenner 2005, Zabala et al. 2018), this sample reflected the unique statements relevant to this study based on the concourse we developed. As is typical with Q studies, we identified participants based on a combination of targeted recruitment and snowball sampling (Zabala et al. 2018), and we selected participants for the diversity in opinions they could provide and for their distribution across Wyoming (Mazur and Asah 2013). Participants in our study consisted of members of the public representing multiple stakeholder groups, including sportspersons, conservationists, outfitters and guides, energy industry, agriculture, and local government. Membership in a stakeholder group was not mutually exclusive; for example, a single participant may be a sportsperson, a rancher, and an outfitter. Some participants were employed by NGOs related to wildlife at the time of participation in the study (Aug–Dec 2019). Other participants were not employed with non-profits or NGOs but instead volunteered their time for working groups, for example. Participants did not include anyone who currently worked for a state or federal wildlife agency, or anyone employed by a university.

Participant Exercise

We interviewed each participant individually and face-to-face. One of the authors (RPJ) interviewed all participants. During the Q-sort exercise, we asked participants, "What factors are most harmful for mule deer across Wyoming at this time?" and asked them to sort the 24 provided statements (Table 1), printed on individual cards, in a forced-choice distribution that resembled a normal distribution. We used a forced-choice distribution because it required participants to make tradeoffs in often difficult decisions, for ease of analysis, and to allow similarity in comparison across participants (Watts and Stenner 2005). After receiving the 24 cards, participants placed these cards on a board with slots that were configured to represent the normal distribution. Participants arranged the statements on a scale from strongly agree (rank = +3, 2 slots) to neither agree nor disagree (rank = 0, 6 slots) to strongly disagree (rank = −3, 2 slots), with intermediate rankings (rank = +/−2, 3 slots each, rank = +/−1, 4 slots each) in between. We used each Q sort to quantify and characterize the viewpoint of each participant. We gave participants instructions on how to complete the ranking exercise and let them complete the exercise with minimal input from the researcher. After participants ranked and arranged the statements, we asked follow-up questions to better understand why they ranked statements in the manner they did. All exercises and interviews were considered exempt from full review because of minimal risk to participants by the Institutional Review Board at the University of Wyoming (protocol 20190801RJ02478).

We collected basic demographic information to better understand the participants who made up each perspective and asked questions regarding wildlife value orientations to understand the connection between perspectives and values. We asked participants their age, how long they had lived in Wyoming, the last time they had accessed information about mule deer through multiple platforms (e.g., newspapers, television, peer-reviewed articles), and the last time they participated in hunting or wildlife watching. We asked participants whether they currently were or previously had been members of organizations that engaged with mule deer management, and we tallied how many participants in each perspective and across perspectives currently were or previously had been members of the various types of organizations. Wildlife value orientations characterize how individuals view the relationship between humans and wildlife (Fulton et al. 1996). Wildlife value orientations

Table 1. Statements used to characterize and delineate perspectives that exist across stakeholders ($n = 37$) regarding mule deer management in Wyoming, USA, in 2019. Factor scores indicate a Q sort that would be representative of a given perspective, where participants ranked along a scale (3 to −3) whether they strongly agree (3) or strongly disagree (−3) with a given statement. The z-scores are untransformed values that form the basis for the factor scores. BU = bottom-up perspective, HC = human contribution perspective, and TD = top-down perspective.

	Factor score			z-score		
Statement	BU	HC	TD	BU	HC	TD
(1) When livestock graze in an area, they can negatively affect the habitat and remove resources otherwise available to mule deer.	0	−2	0	0.25	−0.64	−0.27
(2) Family groups were disrupted by hunting pressures over the past 30 years, and these past pressures are preventing populations from recovering today.	−1	0	−3	−0.96	−0.06	−1.53
(3) Too much pressure from predators such as coyotes, wolves, bears, and mountain lions is the real reason mule deer populations are in trouble.	−3	0	3	−1.26	−0.34	1.92
(4) Coyotes target mule deer fawns and, by killing young, prevent populations from recovering.	−1	0	3	−0.94	0.18	1.92
(5) Vehicle collisions prevent mule deer populations from growing.	0	−2	1	0.08	−1.11	0.36
(6) Humans disrupt mule deer at sensitive times, such as shed (antler) hunting during winter.	1	3	1	0.49	1.31	0.40
(7) Female harvest, past or present, is keeping mule deer from rebounding.	−2	−1	−2	−0.99	−0.59	−1.10
(8) The spread of diseases such as chronic wasting disease (CWD) and adenovirus are hurting the populations we currently have.	1	1	2	0.84	0.47	0.82
(9) The main reason mule deer populations are declining is because of poor habitat conditions.	2	−2	0	1.26	−0.10	0.03
(10) Hunting pressures, such as inappropriate timing of hunting seasons or a large number of tags sold each season, are too high.	−2	2	0	−1.03	1.31	0.30
(11) Mule deer populations are not being negatively impacted by any factors, human or otherwise.	−3	−3	−3	−2.09	−2.35	−1.85
(12) Mule deer habitats are increasingly fragmented because of rural subdivisions, more roads, and energy development, which is affecting their ability to live in those areas.	3	1	0	1.61	0.61	0.20
(13) Seeking to reach current management objectives for population size are causing too many deer to be on the landscape.	−2	−3	−2	−0.99	−1.75	−0.86
(14) The lack of protection for migratory corridors, especially in areas with energy development, is causing migrations to be disrupted, hurting the populations that complete these movements.	2	0	−1	1.09	0.22	−0.40
(15) Harsher winters and drought periods in recent years have strained mule deer populations.	1	1	2	0.76	0.49	0.98
(16) There are many factors impacting populations at once, and it is hard to tell which factor is the biggest player.	0	2	2	0.39	1.22	1.22
(17) Scientists need to improve research methods to properly identify the most influential factors.	−1	1	−1	−0.76	0.34	−0.74
(18) Mule deer winter ranges are in trouble.	3	−1	0	1.39	−0.42	−0.05
(19) Increases in white−tailed deer populations are simultaneously harming mule deer.	0	0	0	0.14	0.24	−0.01
(20) Public and political interests are overriding scientific findings in managing mule deer.	2	3	−1	1.28	1.88	−0.55
(21) The spread of invasive species is changing habitat and making it uninhabitable for mule deer.	0	−1	−1	0.17	−0.62	−0.78
(22) Current forest management, such as preventing burns that clear out the forest overstory, have made summer ranges less ideal for mule deer.	1	0	1	0.40	0.14	0.56
(23) Elk use too many resources, leaving little left over for mule deer to survive on.	0	−1	1	−0.34	−0.50	0.76
(24) Scientists need to conduct more research before we know why mule deer populations are declining and how to protect them.	−1	2	−2	−0.78	0.96	−1.35

include utilitarian (wildlife should be managed for the benefit of humans), mutualist (wildlife should be taken care of and have rights similar to humans), pluralist (a combination of utilitarian and mutualist), and distanced (neither utilitarian nor mutualist views; Fulton et al. 1996, Manfredo et al. 2009). The wildlife value orientation a person holds is related to their support of various management actions (Teel et al. 2005) and receptibility to messaging in communication (Miller et al. 2018). To identify the wildlife value orientations of participants, we asked participants a modified subset of questions from America's wildlife values survey (Manfredo et al. 2018, Rodriguez 2020). We asked participants the degree to which they strongly disagreed (1) to strongly agreed (7) with each prompt (Table 2).

Perspective Interpretation and Statistical Analyses

We identified shared perspectives in participants using principal component analysis (PCA) in the qmethod package (Zabala 2014) using program R (R Core Team 2020). We extracted factors (i.e., clusters of perspectives) based on evaluation of a scree plot, the number of sorts that loaded significantly onto a factor at the alpha = 0.05 level (min. of 3 sorts; Vaas et al. 2019), and the percent of variance explained. If Q sorts loaded significantly onto multiple factors, we only included them in the factor with the highest loading. Finally, we rotated factors using varimax rotation for ease of interpretation (Brown 1980, Watts and Stenner 2005). We interpreted factors by identifying statements with the highest and lowest loading and statements that loaded higher or lower on a given factor than any other factor (i.e., crib sheet method; Watts and Stenner 2005, Vargas et al. 2019). We identified consensus and distinguishing statements by comparing the difference between factor z-scores for a pair of factors with standard error of difference for that factor pair (Zabala 2014). Finally, we used the follow-up interviews with each participant to interpret factors. We identified elements from these interviews by thematically grouping concepts across interviews and extracting comments that helped to explain why a participant held a certain perspective.

From responses to the wildlife value orientation questions (Table 2), we conducted a PCA to reduce the dimensionality of multiple questions. We identified how many dimensions to retain in the PCA using a scree plot and percent of variance explained (Gauttier 2019). We then

conducted a 1-way analysis of variance to evaluate whether there were differences in wildlife value orientations of participants according to the factor they loaded onto (i.e., their perspective). Finally, we conducted a Tukey multiple comparison of means at the 95% confidence level to test for significant differences in wildlife value orientations between perspectives.

RESULTS

We interviewed 37 individuals across Wyoming; 28 identified as male and 9 as female, with participants spread across age groups (18–25 yrs, $n = 1$; 26–35, $n = 5$; 36–45, $n = 9$; 46–55, $n = 6$; 56–65, $n = 13$; 66–75, $n = 3$). Participants lived in Wyoming for an average of 39 ± 18 (SD) years. Most participants (72%) had been or currently were affiliated with a hunting organization, 32% with an outfitting organization, local government, or an environmental or conservation organization, 27% with any mule deer working group, and 16% with a scientific organization (Table 3). Most participants (81%) had hunted in the past 12 months, and all but 1 participant (97%) had participated in wildlife viewing in the past 12 months. Most participants attended a public meeting concerning mule deer in the past 12 months (89%), read a newspaper article about mule deer in the past 12 months (97%), and read a peer-reviewed scientific article about mule deer in the past 12 months (78%).

From the 24 statements, we extracted 3 perspectives (i.e., factors) that represented perspectives regarding the elements that were thought to be negatively affecting mule deer in Wyoming. Together, these perspectives explained 52% of variance (Table 4). Out of all 37 participants, 34 loaded significantly on ≥1 of the perspectives. The remaining 3 participants were between the 3 perspectives, but they did not load significantly on any single perspective. Extracting more perspectives did not increase the number of participants that loaded on a single factor (e.g., extracting 4 factors resulted in 31 participants loading significantly), although the percent of variance explained increased to 59%. We ultimately prioritized capturing the perspectives of as many participants as possible over increasing variance a modest amount.

Perspective 1: Bottom-up

Participants who loaded onto perspective 1 believed that issues concerning conditions of habitats are the elements that are most harmful to mule deer populations in Wyoming.

Table 2. The loading of each statement concerning wildlife value orientations of stakeholders in mule deer management in Wyoming, USA, 2019. Participants ($n = 37$) responded to each statement on a 7-point scale (1 = strongly disagree, 7 = strongly agree). Statements with a negative principal component analysis (PCA) loading represent beliefs from the mutualistic wildlife value orientation, whereas statements with a positive loading represent beliefs from the utilitarian wildlife value orientation.

Statement	PCA loading
I care about animals as much as I do other people.	−0.850
Wildlife should be protected for their own sake rather than simply to meet our needs.	−0.568
Wildlife are like my family and I want to protect them.	−0.555
Wildlife are on earth primarily for people to use.	0.831
The needs of humans should take priority over wildlife protection.	0.874
Humans should manage wildlife populations so that humans benefit.	0.922

Perspective 1, hereafter referred to as the bottom-up perspective because habitat was seen as the limiting factor for mule deer populations (Pierce et al. 2012), was most strongly characterized by the belief that habitat fragmentation (Table 1, statement 12) and condition of winter ranges (Table 1, statement 18) are strongly affecting mule deer. Furthermore, participants in this perspective ranked statements related to overall poor habitat conditions (Table 1, statement 9) and lack of protection for migratory corridors (Table 1, statement 14) higher than individuals associated with any other perspective.

Participants viewed effects concerning direct mortality of an animal, namely hunting pressures (Table 1, statement 10), vehicle collisions (Table 1, statement 5), and predators (Table 1, statements 3 and 4), as less influential (i.e., lower ranking) to mule deer populations than participants in other perspectives. Overall, the ranking of statements suggests that the status of living animals was viewed as more important than direct mortality of animals, and that the status of living animals was directly dependent on their habitat.

Perspective 2: Human Contribution

Participants who loaded onto perspective 2 believed that myriad human contributions were most harmful to mule deer populations in Wyoming. Perspective 2 (i.e., human contribution perspective), was most strongly characterized by the belief that human activity during certain times of the year (Table 1, statement 6) and public and political interests (Table 1, statement 20) are the primary elements negatively

Table 3. The number of participants in Wyoming, USA, 2019, within a given perspective and across perspectives that were currently or previously had been members of organizations that engaged with mule deer management. A single participant may be a member of several organizations.

	Organization					
Perspective	Hunting	Environmental or conservation	Scientific	Outfitting	Local government	Any mule deer working group
Bottom-up ($n = 17$)	14	10	5	5	6	2
Human contribution ($n = 9$)	7	0	1	4	1	4
Top-down ($n = 8$)	4	1	0	2	4	3
No defined perspective ($n = 3$)	2	1	0	1	1	1
Total participants ($n = 37$)	27	12	6	12	12	10

Table 4. Characteristics for shared perspectives regarding factors negatively affecting mule deer in Wyoming, USA. Perspectives were derived from a ranked-order exercise and interviews of participants ($n = 37$) across stakeholder groups throughout Wyoming in summer and autumn 2019. Sorts represents the number of participants that loaded significantly ($P < 0.05$) onto a given perspective. Composite reliability quantifies confidence in a perspective. Values principal component analysis (PCA) represents the mean and standard deviation of the wildlife value orientation for a perspective, with negative PCA values representing mutualist value orientations and positive PCA values representing utilitarian value orientations.

					Values PCA	
	Eigenvalue	Sorts	Composite reliability	Variance explained (%)	$\bar{x}$	SD
Bottom-up	9.46	17	0.99	25.57	−0.39	0.34
Human contribution	5.17	9	0.97	13.97	−0.11	0.44
Top-down	4.62	8	0.97	12.49	1.09	0.31

affecting mule deer populations in Wyoming. Moreover, participants in the human contribution perspective ranked statements about hunting pressures (Table 1, statement 10) and the role of science (Table 1, statement 17 and 24) higher than participants aligned with other perspectives.

Participants within the human contribution perspective ranked statements that concerned habitat—concerns over livestock (Table 1, statement 1), poor habitat conditions (Table 1, statement 9), winter ranges (Table 1, statement 18), and forest management (Table 1, statement 22)—as weaker contributors to the status of mule deer populations than did participants in the other 2 perspectives. Overall, the human contribution perspective viewed human behavior and current approaches to wildlife management as the primary concerns that negatively affect mule deer populations, whereas elements such as habitat conditions were not as important.

Perspective 3: Top-down

Participants who loaded onto perspective 3 believed that direct mortality of mule deer is most harmful to mule deer populations in Wyoming. Perspective 3 (i.e., top-down perspective) included those that thought mortality was the limiting factor for mule deer populations (Pierce et al. 2012) and was most strongly characterized by the negative affect of predators (Table 1, statements 3 and 4) on mule deer. Participants ranked statements that focused on environmental topics that can exert a top-down force on mule deer—statements concerning vehicle collisions (Table 1, statement 5), diseases (Table 1, statement 8), harsher environmental conditions (Table 1, statement 15), and elk (*Cervus canadensis*; Table 1, statement 23)—higher in the top-down perspective than in any other perspective.

In contrast to other perspectives, the lack of protection for migratory corridors (Table 1, statement 14), public and political interests (Table 1, statement 20), and the need for more research (Table 1, statement 24) all ranked lower in the top-down perspective. Overall, participants whose views fell into the top-down perspective tended to identify myriad environmental factors that contribute to the direct mortality of mule deer to be the most problematic factors that are negatively affecting mule deer populations.

Consensus and Distinguishing Statements

Statements about diseases (Table 1, statement 8), white-tailed deer (*Odocoileus virginianus*; Table 1, statement 19), and forest management (Table 1, statement 22) were consensus statements, where participants across all 3 perspectives ranked these statements similarly. Participants ranked all 3 statements towards the middle, indicating that participants across perspectives thought these concerns were relatively less important than multiple other factors for mule deer populations in Wyoming. Notably, the factor arrays for all 3 perspectives strongly disagreed with the notion that mule deer populations are not being negatively affected, although it was not statistically considered a consensus statement (Fig. 1). This similar ranking suggests that nearly all participants agreed that mule deer populations are being affected negatively, even if there was little agreement on the reason for the topics causing the negative effect.

The role of predators on mule deer populations (Table 1, statements 3 and 4) most strongly differentiated the 3 factors. Overall, participants who contributed to the bottom-up perspective disagreed with the notion that predators negatively affect mule deer, participants in the human contribution perspective neither agreed nor disagreed, and participants in the top-down perspective strongly agreed with the notion that predators negatively affect mule deer (Fig. 1). Other statements that distinguished all 3 factors concerned hunting pressures (Table 1, statements 2 and 10), poor habitat conditions (Table 1, statement 9), protection for migratory corridors (Table 1, statement 14), public and political interests (Table 1, statement 20), and needing to conduct more research (Table 1, statement 24).

Additional Themes

In addition to the quantitative results from the Q-sort exercise, qualitative data from the interviews provided insight to concepts that were supplemental to the provided statements. Participants from all perspectives were concerned about the role of science in mule deer management, recognized the multifaceted challenges in mule deer management, garnered at least part of their information regarding mule deer from personal experience, and valued when scientists had personal experience with the landscape.

Participants overwhelmingly noted that they trusted and valued science in mule deer management. Participants especially valued science because it helps to identify appropriate management techniques. For example, 1 participant from the human contribution perspective said, "Now we know exactly what is causing this… we can start to manage this population through the factors that we can manage." Nevertheless, participants at times felt that science could be a delay tactic or that there is sufficient research currently to support actions. One participant from the bottom-up

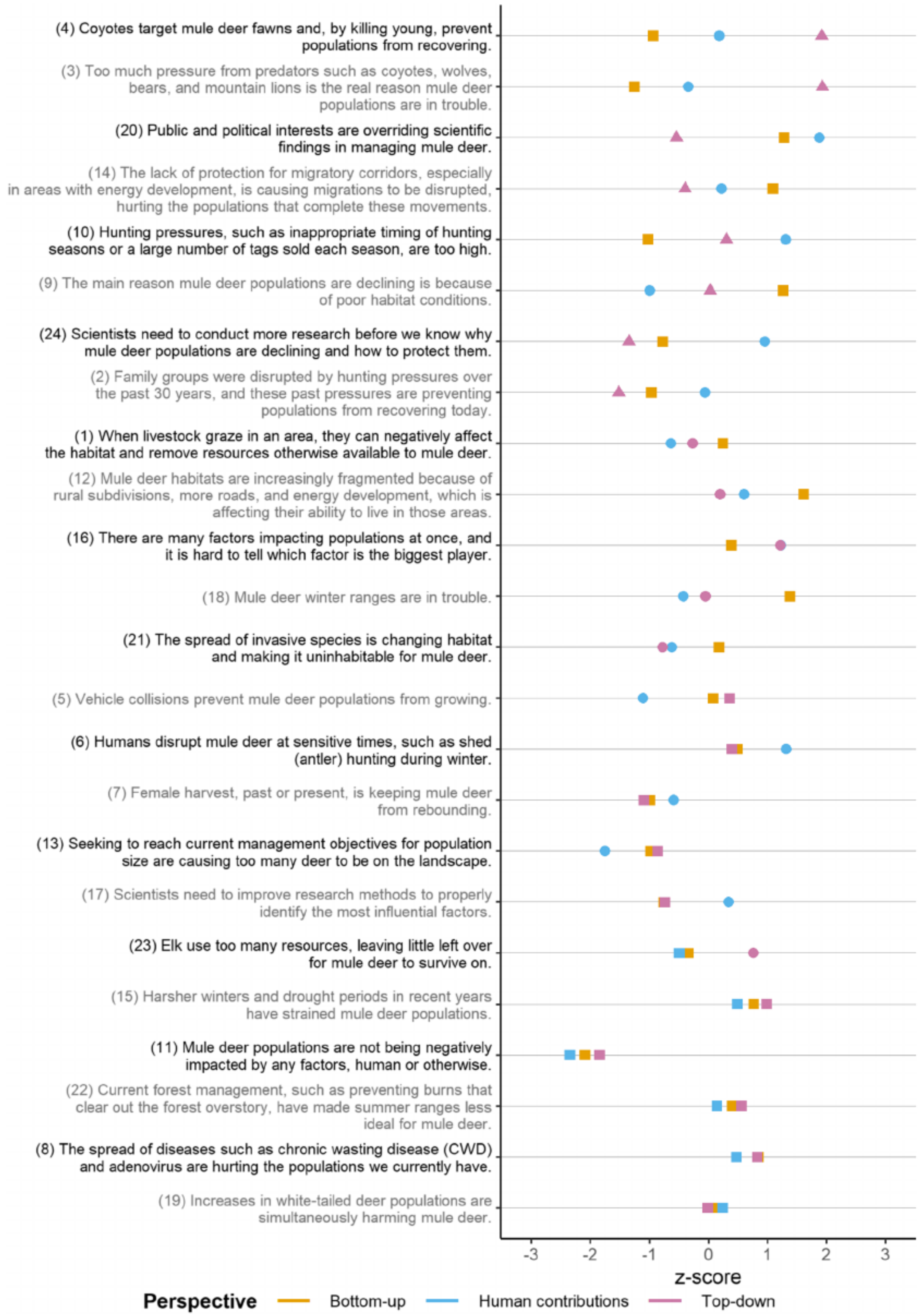

Figure 1. Comparison of statements ($n = 24$) across 3 primary perspectives held by stakeholders ($n = 37$) associated with management of mule deer in Wyoming, USA. Shared perspectives included bottom-up, human contribution, and top-down, which characterized the relative views towards factors negatively affecting mule deer in Wyoming. Z-scores represent how participants in each perspective ranked statements along a scale (3 to −3) ranging from strongly agree (3) to strongly disagree (−3). Statements at the bottom of the figure showed the strongest consensus in how participants ranked a given statement, whereas statements at the top of the figure showed the most divergence. Perspectives reflect shared stakeholder views of the statements based on surveys and interviews conducted in summer and autumn 2019. Different shapes within each statement denote statistical difference ($P < 0.05$) in the z-scores between responses among shared perspectives.

perspective said, "And more research can benefit, it'll always benefit, but I think we have enough research to make decisions at this point." Participants recognized that there were aspects of mule deer management that were beyond the control of science, with 1 participant from the bottom-up perspective mentioning, "You can manipulate the seasons, the dates, the antler restrictions, but mother nature is the one that decides how this herd is coming out in the spring. If she decides they're all going to die, it doesn't matter what you guys do."

Many participants recognized and explicitly mentioned that mule deer management is a multifaceted, complex issue. For example, many participants mentioned that they wished there were more slots on the strongly agree column or in the agree side of the sort because they could not fit all the elements they agreed with in the available slots. Nevertheless, in reference to this statement, 1 participant in the bottom-up perspective stated that, "I put that [Table 1, statement 16] in the neutral area because I think it's in a way a cop out… The reason a lot of people are really interested in finding the 1 silver bullet is because then they can pick an enemy and then kind of make 1 thing out to be an enemy. Where I think in this situation there are a lot of factors and I think they need to be addressed holistically to achieve a better conservation victory." In other words, although there were many elements to consider at once, there were identifiable elements that could be ameliorated. Some suspected that pinpointing specific issues at the expense of a more holistic perspective was almost human nature, with 1 participant that did not load onto any perspective saying, "So I would say it's anything that you can point to specifically as an easy answer. And that just is indicative of all problems that humans face."

Many participants learned about mule deer and what negatively affects mule deer from their first-hand experience on landscapes, and expressly valued when scientists similarly possessed in-depth, first-hand experience with the landscape. As 1 participant in the bottom-up perspective expressed, "I mean they do have some science to back it, but I think that sometimes they rely too heavily on that and don't look at what's happening on the ground and don't listen to, not just the outfitters but the people who [are on the landscape] year in and year out…. Trying to rely too heavily on science and not just common sense." Further, although not opposed to research, 1 participant who did not identify with any of the perspectives noted, "It's more spending the time out there. Spending a lot more time out there," indicating that research without an intimate and direct connection to the landscape and the animals is not sufficient.

The interviews also provided insight on elements that, though not yet a part of the discourse regarding mule deer management, stakeholders thought should be included in such discussions in the future. Multiple participants mentioned that the effects of recreation, such as hiking, mountain biking, use of off-road vehicles, and issues concerning private lands would be worth investigating more seriously in the future.

Wildlife Value Orientations

We reduced the 6 questions about wildlife value orientations to 1 dimension (61% variance explained). Principal component 1 captured the relative difference between utilitarian and mutualist value orientations, with negative loadings indicating mutualist orientations and positive loadings indicating utilitarian orientations (Table 2). A participant's perspective was related to their wildlife value orientation ($F_3 = 5.69$, $P < 0.01$; Table 4). Participants that loaded onto the bottom-up perspective and human contribution perspective and those that did not load significantly onto any factor had answers that were more strongly associated with mutualist values (Table 4). In contrast, participants that loaded onto the top-down perspective displayed more utilitarian values (Table 4). There was a difference in wildlife value orientation between participants in the bottom-up perspective and the top-down perspectives (difference of $\bar{x} = 1.48$, 95% CI = 1.38–1.58, $P < 0.01$), and between the human contribution and top-down perspectives (difference of $\bar{x} = 1.20$, 95% CI = 0.06–2.23, $P = 0.03$). There was no difference between the bottom-up and human contribution perspectives, or between any defined perspective and those individuals who did not load onto a perspective ($P > 0.05$).

DISCUSSION

Perspectives profoundly shape how we conceptualize topics, in wildlife management or otherwise (Vargas et al. 2019). Understanding perspectives among members of the public is integral to identifying appropriate management options and crafting communications (Wolf and Moser 2011), especially when segments of the population hold divergent views (Mazur and Asah 2013, Straka et al. 2020). We identified 3 distinct perspectives across stakeholders who were strongly engaged with mule deer management: bottom-up, human contribution, and top-down perspectives (Table 1; Fig. 1). In the bottom-up perspective, participants considered issues related to the health of the environment and overall habitat conditions to be most important for determining the status of mule deer populations. The bottom-up perspective differed strongly from the top-down perspective, in which participants viewed elements that directly killed mule deer to be the most prominent issues affecting their populations. Finally, in the human contributions perspective, participants considered issues related to human behavior and interests to be most harmful to mule deer. Participants aligning with bottom-up and human contribution perspectives held more mutualistic wildlife value orientations, whereas those aligning with the top-down perspective held utilitarian perspectives. Taken together, these perspectives and participant values illuminate the primary ways that a diversity of stakeholders view the problems that are negatively affecting mule deer in Wyoming and identify areas of consensus or divergence. Whereas previous human dimensions work surrounding ungulates largely focused on concepts such as hunter satisfaction and collaborative processes (Raik et al. 2005, Black et al. 2018, Serenari et al. 2019), our study augments these efforts by providing a glimpse at the basic elements that stakeholders use to construct their

perspectives regarding mule deer. With a better understanding of stakeholders in hand, we see an opportunity to be more responsive to our audiences in tailoring science communication efforts, working towards a goal of improved communication, engagement, and collaboration.

Identifying and understanding areas of consensus and divergence is a component of collaboration (Peters and Ward 2017) and can help with communication strategies. Nearly all participants shared the sentiment that mule deer populations are being negatively affected, but participants identified different issues to be most responsible for that trend. Participants agreed on issues that affected mule deer in ways that were easily observable, were rarely tied to livelihoods, and were not perceived as the primary elements negatively affecting mule deer. For example, participants across perspectives were in alignment, although were neutral, regarding the role that increasing white-tailed deer populations had on mule deer populations (Table 1, statement 19). Participants expressed that they observed encroachment of white-tailed deer and simultaneous displacement of mule deer from their kitchen windows, and white-tailed deer encroachment had relatively little bearing on participants' livelihoods. In contrast, many of the distinguishing statements were issues that vary based on first-hand experience and are often tied to livelihoods. For example, perspectives diverged most strongly on the role of predators (Fig. 1). Livestock predation is a prominent concern to ranchers in Wyoming because of the economic effect, and ranchers develop their ideas related to predators in part from first-hand experience on the landscape (Amit and Jacobson 2017, Windh et al. 2019). Ranchers and non-ranchers likely have different first-hand experiences and anecdotes concerning predators, which are foundational to constructing perspectives (Mutonyi 2016, Wilson et al. 2017). Especially when working with topics where there is substantial divergence among stakeholders, scientists should strategically tailor messaging to respect, incorporate, and address the diverse experiences that stakeholders bring to the table.

Because new information is filtered through already existing values, attitudes, and beliefs (Aipanjiguly et al. 2003, Barney et al. 2005, Manfredo et al. 2018, Miller et al. 2018), we recommend that communications are tailored to first connect with the perspectives we identified, and then build upon that foundation. The purpose and message of any given communication will vary based on the region, state, and stakeholders, making prescriptive recommendations challenging. Nevertheless, if communicating with stakeholders who hold bottom-up, human contribution, or top-down perspectives, communications could first center around the role of habitat conditions, the role of humans in ecological systems, and the factors contributing to direct mortality of animals, respectively. Once scientists make a connection with the individuals within a given perspective, additional messages can be built upon that foundation. In the absence of knowing which perspective an individual holds or which perspective might be most prevalent within a stakeholder group, tailoring communications to reflect all 3 perspectives might help to ensure that individuals across stakeholder groups receive a given message. Across perspectives, many participants currently were or had been affiliated with hunting organizations, suggesting that scientists could focus their communication efforts on those organizations to reach individuals across perspectives. Having a more thorough understanding of the perspectives held by members of the public, as we have done in this study, should aid in tailoring communications to fit within the existing intellectual schema shaped by an individual's experience.

Mule deer management, and most subsets of wildlife management, are ripe with nuance and complexity; however, scientists often ignore many of these complexities in our communication. For example, many of our communication efforts center on a single issue and gloss over the multifaceted nature of ecology, when in reality wildlife populations are often affected by multiple elements working in concert (Forester et al. 2007, Hurley et al. 2011, Pierce et al. 2012, Monteith et al. 2014). Participants across perspectives in our study recognized that mule deer management is multifaceted, suggesting that scientists may be failing to capitalize on an opportunity to communicate nuanced ecological reality with already engaged stakeholders. Although it can be challenging, communicating in an understandable and meaningful way need not obscure complexity so long as non-scientists possess a foundation and frame of reference that scientists can work within (Weber and Word 2001). For example, participants in the top-down perspective noted that predators were the primary factor harming mule deer populations, and these individuals already hold an interest to understand the role of predators in ecosystems. Predators can regulate ungulate populations (Gasaway et al. 1992), although determining the conditions under which regulation occurs is not as simple as measuring predation and is context-specific (Ballard et al. 2001, Bowyer et al. 2014). Communicating rates of predation without the ecological nuance associated with vulnerability to predation and fundamental concepts associated with population ecology (Bowyer et al. 2014, Monteith et al. 2014) could yield misunderstanding and further divergence among perspectives. Scientists could do more to build upon the foundations that stakeholders possess to work towards mutual understanding of complex ecological situations (Weber and Word 2001, Nisbet and Scheufele 2009).

The success of communication, in part, depends on whether the entity communicating is seen as a trusted and credible source (Brewer and Ley 2013). Wildlife managers and researchers are in an ideal position to build on an already high level of trust among the public and leverage this position to improve communication. For example, in a survey of Wyoming voters, 67% and 54% of voters felt that biologists with the state wildlife agency (i.e., Wyoming Game and Fish Department) and wildlife biologists from the only 4-year university in the state (i.e., University of Wyoming), respectively, were very believable sources of information regarding wildlife migrations, a high-profile issue in the state (Bonnie et al. 2020). In Wyoming, 37% of

residents felt their opinions are heard by the state wildlife agency, 39% felt that their interests are appropriately considered by the state wildlife agency, and 44% felt that their input is meaningful (Teel et al. 2005). We recovered this high level of trust and respect across perspectives in our study, but this trust was especially prevalent in the top-down perspective. In post-ranking interviews, participants in the top-down perspective often justified their views using specific information that has been communicated either by the state wildlife agency or the university, such as mountain lions killing a mule deer a week and coyotes targeting mule deer fawns. Such specific references speak to the amount of trust that stakeholders have for the state wildlife agency and the university; however, the trust underscores the responsibility that state wildlife agencies and universities have to ensure that their communications are received as intended and in a way that captures ecological reality.

Scientific evidence is only a single component of building consensus and fostering collaboration for wildlife management (Peters and Ward 2017), and our research highlights the value that stakeholders place in first-hand experience, in addition to science. Participants across perspectives garnered at least part of their information about what negatively affects mule deer from their personal experience with and observations of mule deer, whether from ranching, hunting, or simply driving along a highway. Personal experience and anecdote are powerful ways of building schemas and drawing inferences about the surrounding world (Mutonyi 2016, Wilson et al. 2017), even if these ways of understanding often are not valued by the systematic approach to drawing inferences that is favored by scientists. Biologists are increasingly recognizing the role that local knowledge can play in wildlife management (Austin et al. 2009), and our research suggests that personal experience of scientists could similarly play an important role by improving communication with stakeholders. Participants across perspectives expressed that they valued when a scientist had first-hand experience and knowledge of a landscape; perhaps scientists could use their own anecdotes to spark a conversation and foster trust and credibility with stakeholders. Anecdotes and storytelling can improve science communication (Suzuki et al. 2018, Torres and Pruim 2019), and the value that participants placed on anecdotes about a landscape might be particularly useful when communicating about wildlife management. When talking with stakeholders across perspectives, scientists could demonstrate their first-hand experience by mentioning local geographic names, referencing climactic conditions over the previous years, or recounting how many days they have spent in the field. Additionally, communication events where scientists and stakeholders are in the field together might be productive for building trust and providing an opportunity for more nuanced dialogue.

The discourses identified herein represent those that are prevalent among members of the public that are closely involved with mule deer management. Nevertheless, themes that emerged during this study fall in line with other studies. Participants frequently called for common sense approaches to mule deer management, which was similar to the feeling that government overall fails to use common sense among rural western voters (Bonnie et al. 2020). Additionally, 44% of Wyoming residents hold utilitarian wildlife value orientations, whereas 18% of Wyoming residents hold mutualist wildlife value orientations (Teel et al. 2005). Therefore, the top-down perspective, where participants leaned towards utilitarian wildlife value orientations (Table 4), might be especially prevalent throughout Wyoming. The percent of variance that the 3 perspectives explained (52%) indicates that there are additional aspects that govern how stakeholders view what negatively affects mule deer that we were not able to capture in our study, although this level of variance explained is similar to other Q methodology studies (Zabala et al. 2018). The moderate percentage of variance explained likely stems from the smaller pool of statements we gave to participants; in retrospect, we expect that the 24 statements did not capture all the nuance in how stakeholders conceptualize the factors affecting mule deer. Finally, Q methodology does not permit extrapolating how prevalent each of the perspectives are among members of the public. Despite these limitations, characterizing perspectives serves as a starting point to better understand the layout of stakeholders in mule deer management and to improve communication with these stakeholders.

Identifying perspectives and ways to improve communication are necessary for improving collaboration and engagement among stakeholders, but these efforts alone are not sufficient. Our ability to communicate complexity and nuance, which was an important theme across our study, hinges on the existence of relevant evidence. Nevertheless, most research is narrowly focused and evaluates a single issue at a time. Although science is, of course, incremental, many subjects lack broad syntheses that bring incremental pieces together, which may result in a failure to communicate nuance in ways that are relevant to stakeholders. Communicating complexity with stakeholders across perspectives might necessitate a shift in research approach. Furthermore, embracing nuance and complexity in our communications requires moving away from the deficit model of communication, where scientists relay information to lay audiences, and towards a communication style that favors dialogue between scientists and members of the public (Nisbet and Scheufele 2009). An approach that favors 2-way dialogue over relaying information allows scientists to clarify instances where information may have been miscommunicated and to listen to the personal experiences of members of the public that shaped their knowledge (Hobbs 2006, Decker et al. 2012). Although dialogue-focused communications are more resource-intensive and are not always appropriate (e.g., social media), the high level of engagement and interest among stakeholders suggest that devoting energy to developing communications that promote dialogue (e.g., public meetings) will not be wasted. We see opportunity for scientists to embrace and even feature ecological complexity in communications, so long as the circumstances are appropriate, and to do so by moving away from the deficit model and towards a dialogue-centered communication style. Just as many conclusions in ecology are context-dependent,

approaches to communicating should be similarly context-dependent; by responding to the perspectives, experiences, and values of stakeholders, we may be able to improve communication in a way that promotes engagement and collaboration among diverse stakeholders.

MANAGEMENT IMPLICATIONS

Perspectives held by stakeholders involved in mule deer management in Wyoming were not ubiquitous, underscoring the importance of tailoring communications to the experiences and perspectives of a given stakeholder group. We recommend that scientists customize communications to fit the various perspectives that stakeholders hold regarding mule deer management, embrace complexity and nuance in their communications in appropriate settings, move towards a 2-way style of communication with members of the public that fosters dialogue and conversation, and share first-hand experiences and anecdotes to connect with stakeholders. By improving communication between scientists and members of the public, we hope to promote public engagement with the wildlife management process.

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