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LETTER

# We have a steak in it: Eliciting interventions to reduce beef consumption and its impact on biodiversity

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**Abstract**

Beef production is a major driver of biodiversity loss and greenhouse gas emissions globally, and multiple studies recommend reducing beef production and consumption. Although there have been significant efforts from the biodiversity conservation sector toward reducing beef-production impacts, there has been comparatively much less engagement in reducing beef consumption. As a first step to address this gap and identify leverage points, we conducted a policy Delphi expert elicitation. We asked 16 multidisciplinary experts from research and practitioner backgrounds to propose interventions for reducing beef consumption in the United States. Experts generated and critiqued 20 interventions, creating a qualitative dataset that was thematically analyzed to allow the interventions to be prioritized. Effective, feasible interventions included changing perceived social norms, targeting food providers, and increasing the availability and quality of beef alternatives. This work introduces a conservation research agenda for reducing beef consumption and explores a structured process for prioritizing behavioral interventions.

**KEYWORDS**

beef consumption, behavior change, conservation psychology, green consumerism, interdisciplinarity, meat consumption, nudges, policy Delphi, prioritization, Sustainable Development Goals

## 1 | INTRODUCTION

Agriculture poses one of the greatest threats to biodiversity (Maxwell, Fuller, Brooks, & Watson, 2016), and is a major contributor to greenhouse gas (GHG) emissions (Bajželj et al., 2014; IPCC, 2019). Within agriculture, beef in particular is associated with global and local environmental change (Godfray et al., 2018). Beef production, including feed crops, primarily impacts biodiversity through land conversion (Machovina, Feeley, & Ripple, 2015). It is also a driver of human wildlife conflict (van Eeden et al., 2018), farmland and grassland soil erosion (Lamba, Thompson, Karthikeyan, & Fitzpatrick, 2015), nitrogen and phosphorus pollution (Bouwman et al., 2013), and soil impaction, altering hydrology and ecological communities (Beschta et al., 2013). Compared to other livestock, beef has a larger footprint in terms of area, biomass, GHG emissions, and water use (Gerber, Mottet, Opio, Falcucci, & Teillard, 2015; Hedenus, Wirsenius, & Johansson, 2014).

Many countries already produce and consume beef above sustainable levels (Ranganathan et al., 2016), and global demand for beef is increasing with rising economic

prosperity in newly industrialized countries (Tilman & Clark, 2014). Without targeted interventions, beef production will increasingly impact biodiversity and ecosystem services, reducing future capacity to feed the global population (Clark & Tilman, 2017). By specifically targeting beef consumption, and working in collaboration with other relevant stakeholders (Toomey, Knight, & Barlow, 2017), the conservation sector could help incentivize reductions in beef production, mitigating this key driver of biodiversity loss and GHG emissions.

Existing conservation efforts targeting beef have focused on reducing the impact of beef production, including through "sustainable feedstock" (Nepstad et al., 2014) and incentives for reducing stocking rates (Lindenmayer et al., 2012). Both grass-fed (e.g., rockies.audubon.org/programs/audubon-conservation-ranching) and concentrated animal feeding operations (CAFOs) have been championed (Swain, Blomqvist, McNamara, & Ripple, 2018). However, the biodiversity benefits and potential reductions in GHG emissions associated with both are disputed (Beschta et al., 2013; Garnett et al., 2017). Further, these systems face additional challenges: the land requirements of grass-fed beef are prohibitive (Eshel et al., 2018), and CAFOs raise animal welfare issues (Shields & Orme-Evans, 2015).

Recent research has recommended targets and policies to reduce beef production and consumption in the United States and globally (Bajželj et al., 2014; Eshel et al., 2018; IPCC, 2019; McAlpine, Etter, Fearnside, Seabrook, & Laurance, 2009). Because reducing economic subsidies for beef production or regulating beef production and consumption is politically unpalatable in many parts of the world, relying on government policy to tackle the problem may be unrealistic (Dagevos & Voordouw, 2013). In the absence of policy changes, effective strategies to change consumer choices—for example, switching to plant-based protein sources (Harwatt, Sabaté, Eshel, Soret, & Ripple, 2017) or to other meat products with lower biodiversity footprints (e.g., pork, chicken, and sustainably sourced fish)—are required. Understanding how to most effectively influence individual behaviors that have the greatest impact on biodiversity has been identified as an important aspect of conservation science (Schultz, 2011), yet conservation behavior change research into the demand side of the drivers of biodiversity loss is still an emerging field (Selinske et al., 2018).

Although there is a growing body of research examining the factors that influence meat consumption (Stoll-Kleemann & Schmidt, 2017), few studies test behavioral interventions aimed at reducing meat consumption (Garnett, Balmford, Sandbrook, Pilling, & Marteau, 2019; Hartmann & Siegrist, 2017). Even fewer studies specifically examine beef consumption (Klöckner & Ofstad, 2017). The paucity of such research may be influenced by perceptions of the limited political and social appeal of reducing beef consumption (Laestadius, Neff, Barry, & Frattaroli, 2014).

To generate potential interventions for reducing beef consumption and explore their limitations, we undertook a formal elicitation using experts from multiple relevant disciplines. By engaging interdisciplinary expertise outside of the conservation sector, we aim to draw on previous knowledge and evidence bases to inform a conservation research agenda for addressing the biodiversity impacts of beef consumption. We focused our elicitation on the United States because it is the largest beef producing and consuming nation, and the fifth highest per capita beef consumer, behind Uruguay, Argentina, Paraguay, and Brazil (OECD, 2018).

## 2 | METHODS

To identify the interventions that are most likely to achieve reductions in beef consumption, we used a policy Delphi to elicit information from experts on food choice and behavior. The Delphi method is a structured multi-round exercise (Figure 1), employed to understand complex issues for which there is little background knowledge (Turoff, 1970). Similar to other Delphi processes, the policy Delphi engages experts anonymously through structured interactions over multiple rounds of elicitation, allowing for revisions of opinions or estimates (Turoff, 1970). It deviates from other Delphi methods in that it is not intended to lead to consensus around an issue, but rather to consider policy interventions, and to discuss their pros and cons in depth (de Loë, Melnychuk, Murray, & Plummer, 2016).

### 2.1 | Expert participants

We identified experts using a nonprobability sampling method (Teddlie & Yu, 2007), by examining author lists of published literature derived from a search on Google Scholar (scholar.google.com) of articles published from 2010 to 2017 that contained "beef consumption" AND "behavior change" in the keywords, abstracts, or titles. We sought lead authors with multiple publications related to the topic and examined the reference lists of papers returned in the literature search to identify key literature related to changing beef consumption or meat consumption more generally (snowball sampling [Teddlie & Yu, 2007]). We also invited authors to provide recommendations of other appropriate experts. As diversity is a key element of successful expert elicitations (Hemming, Walshe, Hanea, Fidler, & Burgman, 2018), we purposefully selected experts from different disciplines and included academics and practitioners.

Expert panelists were recruited in April 2018. Thirty-one experts were contacted by email, of which 19 agreed to participate and 16 participated in both rounds of our elicitation (see Section 2.2, below). Although the research topic has a U.S. focus, because many of the leading experts

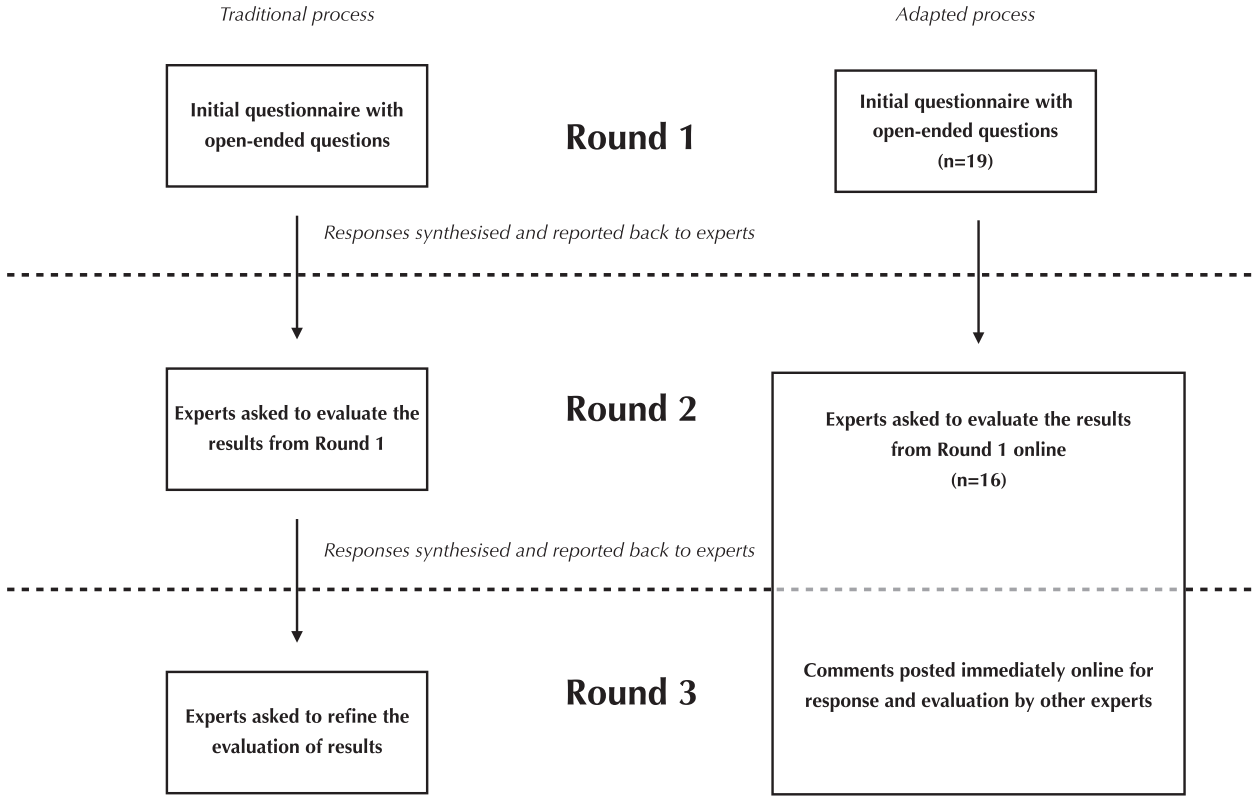


**FIGURE 1** The adapted policy Delphi process followed in this study compared to the a more traditional approach (de Loë et al., 2016; Turoff, 1970)

*Note*. The number of participating experts in this research are included for each round.

on meat and beef consumption are not based in the United States, we recruited more broadly. Although meat consumption and effective interventions are likely to vary across individuals and geographical areas, it is useful to consider experiences from other contexts, which could be applicable to the U.S. context if adapted appropriately. Participants included experts from the fields of consumer psychology, environmental psychology, public health, human geography, food psychology, mass communication, social psychology, sociology, and public policy (Table S2).

## 2.2 | Expert elicitation process

The elicitation took place in two rounds. In Round 1, each expert participated in an online survey, hosted by the Qualtrics survey platform (https://www.qualtrics.com/) for 5 days (May 28 to June 1, 2018). Responses to the survey were recorded anonymously. Survey questions pertained to the societal and behavioral factors that drive beef consumption in the United States (Figure S1) and the types of interventions that could be implemented to reduce beef consumption. After nominating potential interventions, experts were asked to categorize them into three time horizon categories: short term (0–12 months), intermediate (1–10 years), and long term (10–40 years) (Coleman, Hurley, Koliba, & Zia, 2017). Given the urgency of biodiversity loss, experts were asked to select up to three interventions that they believed to be most effective and feasible within a short or intermediate time horizon and to provide a justification and description for each suggested intervention. Finally, experts were asked to suggest fruitful ways for conservation science to contribute toward reducing beef consumption (see Supporting Information).

Round 2 took place over a 3-day period (June 5 to June 7, 2018) using SWARM (https://www.swarmproject.info/), an online expert judgement and reasoning elicitation platform. We aimed to facilitate online discussion about the most promising short- to medium-term interventions proposed during Round 1, with a particular focus on feasibility and effectiveness. Experts were located around the world and participated anonymously at different times over the 3-day period. To maintain each expert's original intent, the titles and descriptions of interventions were retained in the same form that they were proffered during Round 1. Where interventions suggested by different experts in Round 1 were substantially similar to one another, the responses were combined in a way that maintained the integrity and rationale of each suggestion. The interventions were posted online by the author (MJS) and experts were invited to critique each intervention through online discussion threads. Experts were encouraged to comment as many times as they wished,

representing an innovation to the policy Delphi method, and allowing for an iterative approach to obtain more robust opinions from experts (Figure 1).

### 2.3 | Analysis

Qualitative thematic analysis of elicitation Rounds 1 and 2 were undertaken by two of the authors (MJS and AK). All responses were double coded and coding disagreements were resolved through discussion. Suggested interventions were coded based on 11 a priori categories of factors driving meat consumption as defined by Stoll-Kleemann and Schmidt (2017) (Table 1). Critiques and other expert comments derived from Round 2 were thematically analyzed to assess how the experts collectively viewed the effectiveness and feasibility of each intervention.

## 3 | RESULTS

### 3.1 | Round 1: Intervention generation and selection

Experts generated a list of 90 interventions to reduce beef consumption, with those addressing "knowledge and skills" being the most common (Figure 2; Table S3). Of the interventions identified, 41 (45.6%) were unique; the remainder overlapped with one or more of the other expert-derived interventions. Experts nominated 25 interventions as effective and feasible in the short to medium term, spanning multiple stages of the beef supply chain (Table 2; Figure 3). Of these, 20 were unique and formed the basis of the Round 2 elicitation.

### 3.2 | Round 2: Expert critiques of interventions

The major discussion points for each intervention, derived from expert opinion, are summarized in Table 2. Experts agreed on four interventions they felt were likely to be effective in reducing beef consumption and feasible within a 10-year time frame: "Manipulate perceived dynamic norms" (Intervention 6); "Further development of beef alternatives" (Intervention 11); "Beef-free meals in student, work, and prison canteens" (Intervention 12); and "Advocate for greater proportion of beef-alternative purchases by large-scale distributors of meals" (Intervention 13). Intervention 6 (relating to social norms) was generally agreed to be effective with potential long-term implications for those individuals subjected to it, and to be highly feasible as there is a "lot of activity in the space." The two structural interventions 12 and 13 were deemed to be highly effective as they bypass individual decision-making, though experts cautioned that to be feasible these types of interventions need to be well-executed through corporate outreach and effective marketing and incentivized by promoting corporate social responsibility and developing a business case. Intervention 11 was thought to have high feasibility and effectiveness, given the continued development of alternatives and market uptake.

The interventions targeted different leverage points within the beef supply chain (Figure 3). Although some leverage points were thought to have higher impact than others, experts made the point that multiple interventions across the supply chain were required to successfully reduce beef consumption, with some interventions potentially reinforcing others. In general, interventions that focused on psychological behavior changes (changes to knowledge, skills, attitudes, and values) were perceived by experts as having high feasibility but low effectiveness. Conversely, structural interventions (changes to food environment and political or economic factors), particularly policy changes, were generally thought to have high effectiveness but low feasibility. Some experts emphasized that outright banning of beef will have low feasibility and could result in strong pushback from consumers and special interest groups.

## 4 | DISCUSSION

The policy Delphi expert elicitation provided insights into potential interventions to address key factors driving beef consumption in the United States and the challenges that reduction efforts will face. During the initial elicitation, the experts contributed a comprehensive and diverse list of interventions, many of which addressed knowledge and skills-based drivers of consumption. Although there is a need to raise public awareness of the link between beef consumption and environmental issues (Neff et al., 2018), the limitations of the knowledge-deficit model for creating behavior change are well known (Heberlein, 2012). In the second round, experts disagreed about which interventions would be most appropriate within a 10-year timeline, and whether some interventions should be pursued at all. For instance, the development of beef alternatives—despite being recognized by experts as an intervention that will likely be effective in reducing beef consumption—drew criticism from some experts who felt that it might reinforce a view that meat consumption is appropriate (it is unknown if there is evidence that supports this). Additionally, flexitarianism (meat consumption in moderation) interventions are unlikely to be satisfactory for those that are focused on the ethical implications of animal consumption but have great potential to reduce biodiversity and climatic impacts.

There was general agreement that structural interventions such as influencing the practices of major food suppliers and service providers could have a large effect in reducing beef consumption. Given the political and economic factors that drive beef consumption, structural approaches that engage

**TABLE 1** Definitions of factors driving meat consumption adapted from Stoll-Kleemann and Schmidt (2017)

| Factors | Definition |
|---|---|
| Knowledge and skills | Factual knowledge of beef's impact on the environment and procedural knowledge of how to cook without beef. |
| Values and attitudes | Principles that guide decision-making in the consumption of beef. For example, if an individual does not perceive an ethical or health issue in eating beef, they are unlikely to change their consumption habits. |
| Emotions and cognitive dissonance | Affective responses of feelings and sensory experiences of eating beef. Cognitive dissonance is a state of inconsistent attitudes and a barrier to experiencing emotions and behavior change, for example, holding pro-environmental attitudes yet resistant to reducing beef consumption |
| Habits and taste | Unconscious routine of buying beef at a restaurant or supermarket and taste preferences towards beef. |
| Socio-demographic variables and personality traits | Gender, age, income, education, and personality may influence the consumption of beef. |
| Perceived behavior control | Lack of self-efficacy reduces the control over or the likelihood of reducing beef consumption. |
| Culture and religion | Beliefs and symbolism attached to beef consumption. |
| Social identity and lifestyles | Beef consumption as a signifier of social status and identity—people define themselves based on personal and social aspects. |
| Social norms, roles and relationships | Perceptions of how to behave in a particular social group and the expectations of that group around beef consumption. |
| Political and economic factors | Power relationships between government and agro-industry, subsidies, and the costs of purchasing beef and alternative products. |
| Food environment | The available alternatives to beef and the infrastructure such as restaurants or grocery stores that deliver and shape food decisions. |

business directly to attempt to change consumer decision-making environments may be preferable to attempting to change governmental policy (Dagevos & Voordouw, 2013). However, interventions such as sustainability ratings and dietary guidelines for reduced beef consumption have been possible under previous U.S. leadership and may be again in the future (Merrigan et al., 2015). Experts also agreed that dynamic norm-messaging targeting changes in beef consumption would likely be effective (e.g., Sparkman & Walton, 2017) and comparatively easy to rollout, although normative appeals have the potential to backfire if not executed properly (Farrow, Grolleau, & Ibanez, 2017). Other "nudges" (e.g., making nonbeef options a default choice, or rearranging menus to alter consumer choices) may also be useful in to reducing beef consumption (Garnett et al., 2019). However, these kinds of interventions will likely require multiple strategies and their design and effectiveness will be dependent on context (Arbit et al., 2017; Hartmann & Siegrist, 2017; The Behavioural Insights Team, 2020). As demonstrated in a recent review of pro-environmental meat consumption studies, more research, including experimental studies, is required to improve understanding of effective ways of changing consumption behaviors (Hartmann & Siegrist, 2017).

There are a number of challenges associated with some of the suggested interventions, such as the ongoing presence of policies that incentivize beef production and consumption, and pushback from special interest groups and other resistant segments of the public (Stoll-Kleemann & Schmidt, 2017). Given entrenched interests of the beef industry in the United States and elsewhere, systematically targeting beef consumption presents risks such as political pressure from actors aligned with the beef industry (Dagevos & Voordouw, 2013) and further polarizing environmental/climate skeptics and those who may not respond to assertions of moral responsibility to protect the environment, against the conservation sector (de Boer, de Witt, & Aiking, 2016; Feinberg & Willer, 2013). Thus, when engaging with interventions to reduce beef consumption, we recommend the conservation sector exercise caution, by avoiding perceptions that individual choices are constrained, and potentially countering misinformation about plant-based diets or the meat industry (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012).

Socioeconomic and geographic factors may play an important role in consideration of meat substitutes and more sustainable consumption (Stoll-Kleemann & Schmidt, 2017). The per capita rate of beef consumption in the United States is fairly stable (Neff et al., 2018), but increasing population and changing dietary norms in urban areas presents opportunities to increase the effectiveness of interventions that are targeted at these groups (Stoll-Kleemann & Schmidt, 2017). Additionally, making sustainable consumption available to all socioeconomic groups, through reducing cost barriers to

**TABLE 2** Interventions selected by experts to be both effective and feasible within a 10-year time horizon, including intervention description, target audience, and a summary of expert comments

| Intervention* | Description | Target audience | Summations of expert critiques and opinions |
|---|---|---|---|
| 1. Health messaging/social marketing campaign | Provide individuals with information about health impacts of consuming beef, benefits of eating alternatives, and how to implement dietary changes. Health-related arguments often resonate better with larger groups of the public than environmental arguments. | General public | Interventions may have **low effectiveness** and **high feasibility**Based on the assumption of knowledge deficit model that is less effectivePublic views on the health benefits of beef consumption could be contradictory challenging the interventions' efficacy |
| 2. Challenge misrepresentations and misunderstandings of (a) plant-based diets and (b) livestock production | Directly counter negative and inaccurate conceptions of plant-based diets using science-based evidence. Increase understanding of production methods, including the economics, nutrition, and impact to livestock during production. | General public | Interventions may have **low effectiveness** and **high feasibility**Based on the assumption of knowledge deficit model that is less effectivePotentially appeal to limited segments of the public |
| 3. Cooking classes without beef in schools to promote and form early cooking habits that exclude beef | Preparing meals with beef can be habit forming. As habits are formed early, it is important to learn how to cook and form cooking habits that exclude beef. Cooking skills can be taught at schools, in conjunction with promoting healthy eating. | Schools and their students | Experts perceived that the **feasibility may be high** for implementation but **effectiveness low**May not have uptake as there is a gap between learning and practiceImplementation dependent on uptake of schools and teachers |
| 4. Better nutrition education for physicians in medical school as they currently receive little training on nutrition, and even less on the environment impacts of diet choices. | Currently, physicians receive little training on nutrition, and even less on the environment impacts of diet choices. With rational arguments physicians could counsel their patients to make improved dietary choices. This may compel groups like the American Medical Association to support policy changes direct toward beef consumption | Physicians in medical school | Experts perceived that the **feasibility may be high** for implementation but l**ow effectiveness** as it is a niche strategyPeople do not always listen to health professionals' diet advice and this likely extends to the environmentHealth marketing might be more effective than a physician's advice |
| 5. Challenge the normalization of "food animals," by highlighting and questioning the conceptions of food animal farming as natural, and understandings of meat as natural and necessary | Changing the language used to discuss livestock may start to counter and unsettle normalized constructs related to beef consumption. This would introduce the opportunity to think, talk and act differently with regard to constructs of "meat," "beef," and "food" animals. | General public | Experts **questioned feasibility** in the short termQuestioned how to deliver or scale-up the interventions due to their abstract natureWould receive significant pushback from segments of the public and special interests**Potentially effective** if led by high profile members of society |

(Continues)

**TABLE 2** (Continued)

| Intervention* | Description | Target audience | Summations of expert critiques and opinions |
|---|---|---|---|
| 6. Manipulate perceived dynamic norms by framing information of plant-based consumption | Frame plant-based meals as increasingly popular and mainstream. Providing information about how behaviors toward consuming beef are changing can cause people to "preconform" with pro-environmental behaviors that contradict the status quo before they become mainstream. | General public | General agreement of **high feasibility** and **high effectiveness**Potential long-term implications for those individuals exposedChanging norms works well in conjunction with other interventionsPotential perverse outcome for those who like to be different from the majority |
| 7. Meat/Beef Free Days campaign to agree to go meat/beef free at least one day per week | Information and a campaign to encourage the general public to eat meat/beef free meals the entire day at least 1 day per week. Resources required include a small amount of funds to set up the initiative and maintain momentum, and provide how-to guides. Generally, this involves the main evening meal. | General public | General agreement of **high feasibility**, **mixed feelings on its effectiveness**Meat/Beef free days intervention could also be impactful if broad and catches onCriticism that it is currently undertaken by people who are already contributing |
| 8. Online tailored behavioral interventions delivering targeted information designed to answer consumers questions and challenges they have at the moment | This intervention is for those attempting to reduce their beef consumption and starts with detecting where in the process of change people are. Then, with an app or online platform, people receive targeted information designed to answer the questions and challenges they have at the moment. | General public especially those engaged in reducing their beef consumption | **Mixed beliefs if this could be an effective and feasible intervention**Addresses multiple factors including knowledge, skills, attitudes, and social normsExperts challenged the conceptualization of behavior change as a "linear process"Other experts liked the interventions framework—useful in conjunction with other types of interventions |
| 9. Include reduced beef consumption in 2020 U.S. dietary guidelines to influence school lunch | Ensure that scientific recommendations of reduced beef consumption are included in 2020 U.S. Dietary Guidelines. These guidelines form the bases of school lunch programs and are a major educational tool for the public at large. | U.S. government | Consensus among experts these interventions will have **high effectiveness** and broad reach because of its impact on school lunch programsSpecial interests and potentially parents may **dampen feasibility** and challenge implementationLittle impact on public as they pay less attention to health guidelines |
| 10. Include environmental considerations in 2020 U.S. dietary guidelines | Consideration of environmental health as well as nutrition in the guidelines would lead to a recommendation for reduced beef consumption, which would filter down to schools and nutrition programs. Nearly achieved in previous U.S. Congress but was thwarted by special interests. | U.S. government | Similarly, to Intervention 9 the consensus among experts these interventions will have **high efficacy** and broad reach because of its impact on school lunch programsSpecial interests and potentially parents may **dampen feasibility** and challenge implementationFuture research could focus on how consumers engage with sustainability ratings |

(Continues)

**TABLE 2** (Continued)

| Intervention* | Description | Target audience | Summations of expert critiques and opinions |
|---|---|---|---|
| 11. Further development of beef alternatives that look, taste, and smell like beef without the same negative impacts on the environment and animal welfare | Continue making advances in food science so that people can eat things that look, taste, and smell like beef without the same negative impacts on the environment and animal welfare. Create affordable plant-based or cultured meat alternatives that are viable alternatives to beef. | Meat substitute industry and companies | Has **high feasibility** as there is continued investment and **high efficacy** given uptake from food retailers, mediaLikely achievable in 10 years' time, with existing products in the market and continued developmentThere was concern that people may resist imitation meats as undesirable and there may also be environmental impacts from the alternative productsPotentially does little to shift the underlying attitudes and norms towards eating meat (it is unknown if there is evidence that supports this). But a key step in overall reduction. |
| 12. Advocate for major food service companies to commit to cutting purchases of beef and increasing purchases of beef alternatives | Campaign major food service companies to commit to cutting purchases of beef and increasing purchases of vegetable-based meals. The business models of large-scale sellers of meals, like the major food service companies in the United States, require them to more responsive to increasing demand for plant-based meals | Large food distributors that sell prepackaged meals, and meals to large food | **High efficacy** as it bypasses individual decision-making and broad reach**Feasible but difficult**, needs to be well executedTo increase feasibility, incentivize participation by promoting the corporate social responsibility and developing a business case |
| 13. Institutional Reform to include beef-free meals in student, work and prison canteens | Convince large institutions, such as cafeterias, prisons, and schools, to reduce their meat consumption by10–20%. This intervention may go unnoticed to many consumers. Institutional reform already has a proven track record in the US and could be significantly scaled up and intensified. | Large food providers such as school cafeterias | Like Intervention 12 it is **highly effective** as it bypasses individual decision-making; **feasible but difficult**Experts suggested focusing on reduction of meat-based meals rather than a banPotential for backlash and unintended consequence- increased beef consumption elsewhere |
| 14. Internalize the environmental cost of beef to ensure the societal cost is included in the consumers price | Including the environmental costs of beef production into the product will ensure the societal cost is included in a consumer's price and incentivize other forms of consumption. | Cattle farmers, food providers | Likely will be **effective** and have broad impact as a result of increased price for beef but low feasibility as a result of the resistance to increasing the cost of beefWould be a polarizing policyExperts **questioned the feasibility** of fully accounting for and robustly monetizing the greenhouse gas (GHG) emissions and indirect costs of land clearing associated with beef productionAn expert suggested alternative intervention—apply these metrics to a marketing campaign, raising the profile of beef's environmental costs |

(Continues)

**TABLE 2** (Continued)

| Intervention* | Description | Target audience | Summations of expert critiques and opinions |
|---|---|---|---|
| 15. End the Beef Check-off Program to terminate the marketing of beef in the US as a product in itself (https://www.beefboard.org/about/faq_aboutcheckoff.asp) | Commodity check-off programs such as the beef check off program (https://www.beefboard.org/about/faq_aboutcheckoff.asp) require producers to support generic advertising campaigns for their products. Ending this would end marketing for beef as a product in of itself. | US government | All responses **questioned the feasibility** due to political power of beef industry but it would reduce the marketing power of the beef industry so it would **have high effectiveness**Alternative proposal suggested to create a "tofu check-off" program funding advertising for plant-based meals |
| 16. Change and reduce the availability of beef in restaurants, supermarkets, and menus | Reduce the availability of beef and increasing the availability of alternatives by presenting the alternatives earlier and more often in buffets, and placing beef options further down on menu. | Restaurants, supermarkets | Any reduction of availability through costs, menu structure, or availability and visibility of beef alternatives have shown to **be effective**Outright bans will be difficult and met with pushbackDebate might create awareness about the importance of reducing beef consumptionNoted that this was less a single intervention but multiple interventions |
| 17. Foster better conditions and training for small-scale cow/calf operators through policy and research efforts | Policy and research efforts should be directed toward improving the livelihoods and security of rural communities and finding ways to foster environmental sustainability therein—including for cow/calf operators. Market pressures often drive farmers out of business or into bigger operations. Find ways to relieve these pressures and encourage multiple land use practices that are more sustainable. | Cattle farmers | The intervention was seen as a **low disruption so easily feasible**Will help husbandry for small growers and a shift to more sustainable agricultureFor some experts was seen as providing a license for beef consumptionIt was noted that this intervention doesn't shift consumption |

*Note*. Comments pertaining to effectiveness and feasibility are in bold. Three interventions elicited little discussion and are not included: "Strategic communication campaign," "Encourage consumers to eat more plant-based meals rather than other meats," and "Promoting greater reflexivity as to the complex drivers behind industrial meat consumption." In each case, experts expressed that the intervention lacked sufficient description or reasoning to enable meaningful discussion.

*An unedited and full description of each intervention is available in Table S3.

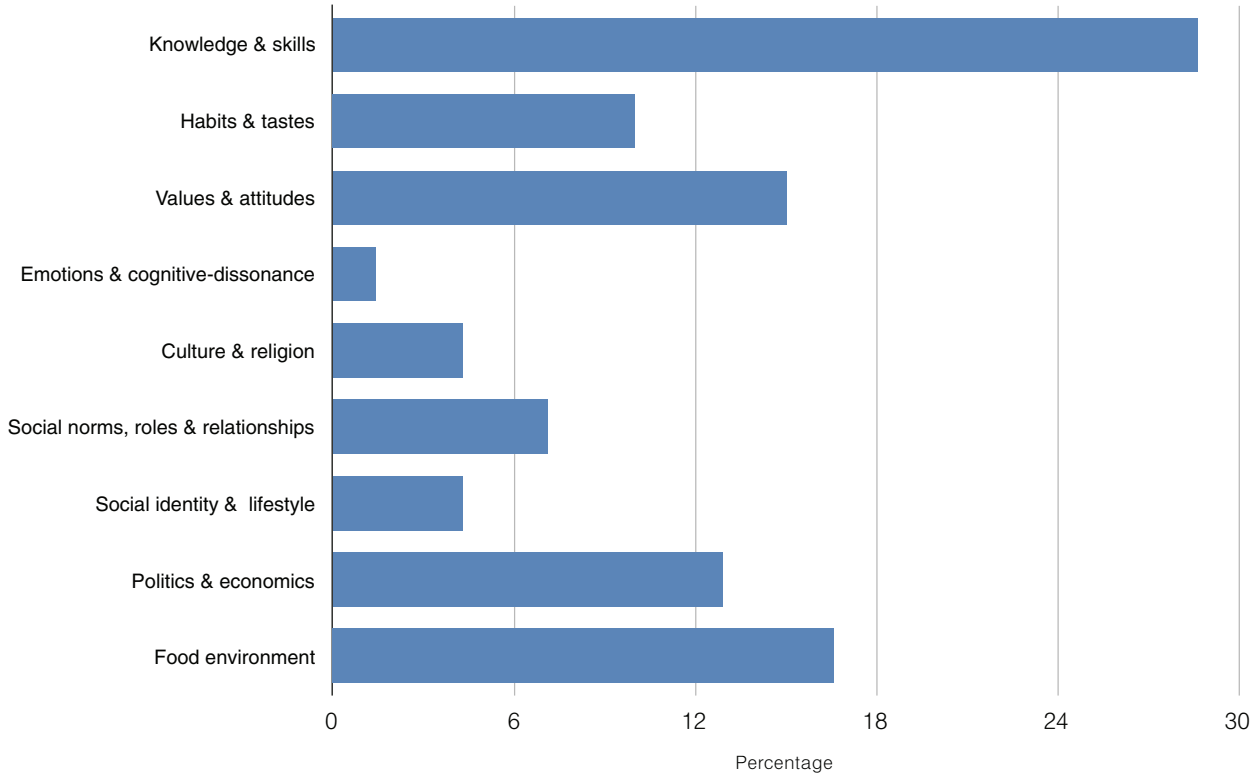


**FIGURE 2** The percentage of expert generated interventions (90 in total) classified by the category of factors addressed
*Note*. The categories were identified by Stoll-Kleemann and Schmidt (2017) as factors driving beef consumption. Two categories—"Perceived Behavior Control" and "Sociodemographics/Personality"—identified by Stoll-Kleemann and Schmidt (2017) were not raised by experts in this sample.

meat substitutes, could be key to promoting both sustainable and healthy lifestyles (Arbit et al., 2017).

## 4.1 | Establishing a conservation research and practice agenda to reduce beef consumption

The intention of this elicitation was not to single out one intervention to target for better biodiversity outcomes; "there is no silver bullet" in reducing beef consumption (Ranganathan et al., 2016, p. 14). Instead, we aimed to stimulate thinking about this interdisciplinary conservation issue and outline a research agenda for effective approaches for reducing beef consumption. Behavior change is increasingly recognized as an important component of biodiversity conservation and it is necessary to experimentally test candidate interventions to inform conservation practice (Hartmann & Siegrist, 2017). For instance, research investigating links between awareness of the biodiversity impact of beef and reduced beef consumption, including how increased biodiversity awareness influences or displaces other (e.g., climate and health) motivations for reducing beef consumption, could make an important contribution to biodiversity conservation (de Boer et al., 2016).

There is also a meaningful role for conservation nongovernmental organizations, who can utilize their previous experience in campaign implementation to engage and/or pressure large food suppliers, encourage supporters to reduce their own beef consumption, and actively lobby governments to support policies that reduce beef consumption and engender farmer stewardship. There is an opportunity for conservation researchers to collaborate with and learn from organizations like the World Resources Institute (www.wri.org/our-work/project/better-buying-lab), which are already engaged in research and practice on both the production and consumer end of beef supply chains. As evident in the discussions during our elicitations, engaging in this space will require careful and strategic consideration including the balancing of competing goals, such as promoting biodiversity-friendly beef production while actively reducing beef consumption. However, if the conservation sector is to truly make inroads in reducing biodiversity loss, then this is the kind of problem that the research community must engage in, notwithstanding that it is a difficult and contested space.

## 4.2 | Limitations

Our study focused on beef consumption in the United States. Although it is likely that these interventions can be applied to other contexts, some may be inappropriate for other nations with high beef consumption and thus should be considered and tested in specific contexts (Graça, 2016). It's also likely

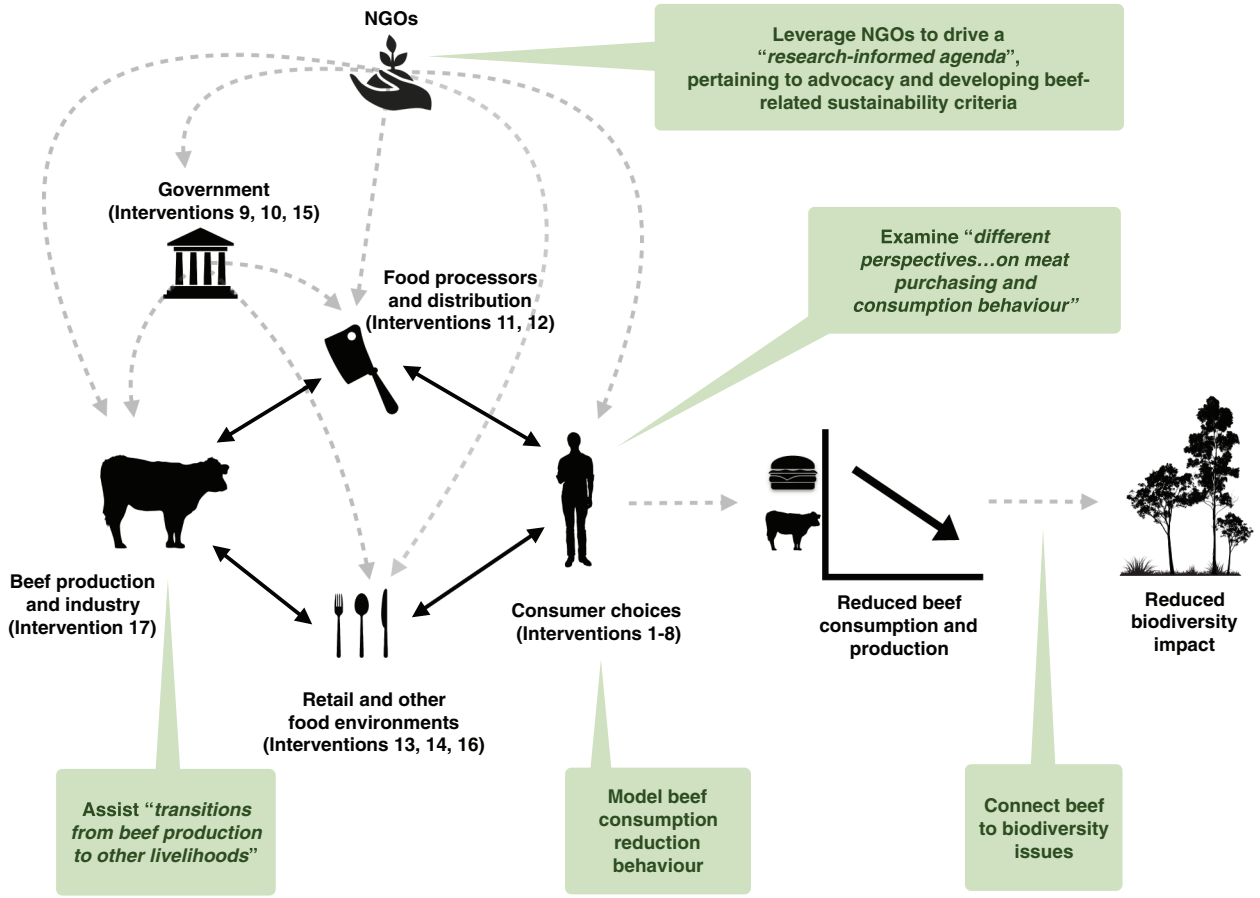


**FIGURE 3** Graphical representation depicting the suggested interventions in the beef supply chain and related points of leverage
*Note*. Intervention numbers correspond with those in Table 2. Dashed lines represent indirect influence from government, NGOs, and production/consumption. Green boxes are roles for conservation science and practice, as suggested by experts (Supporting Information).

that some interventions may have been overlooked; our study should not be viewed as a complete list and repeating this process with different experts or experts from other disciplines such as economics may uncover additional interventions (e.g., McAlpine et al., 2009). Although we found the policy Delphi to be an effective tool for rapidly generating a list of potential interventions and understanding the challenges in implementing them, experts tended not to engage with interventions for which only minimal background information was provided, thereby potentially favoring interventions that were described in greater detail. Additionally, the suggested interventions differed in specificity and scale and as a result received different types of criticism, potentially resulting in inconsistent comparisons of interventions. Finally, the outputs from the elicitation do not constitute empirical evidence for the expected effectiveness and feasibility of the suggested interventions; rather, they should be viewed as a first step that prioritizes and informs the conservations sector's engagement in beef consumption behavior change.

## 5 | CONCLUSIONS

Beef production has a significant impact on biodiversity and global GHG emissions, and even with production efficiency gains there are no scenarios under which the world's population can live within our planetary boundaries on a U.S. level of beef consumption (Bowles, Alexander, & Hadjikakou, 2019). Understanding and reducing the drivers of beef consumption potentially offers a more effective, longer term strategy than changing production practices (Poore & Nemecek, 2018). We have explored a process for eliciting and prioritizing a diversity of potentially effective and feasible interventions for reducing beef consumption. The policy Delphi employed here revealed a diverse range of interventions required for tackling an entrenched behavior like beef consumption. For the foreseeable future beef consumption will not be eliminated, but our study has revealed a number of potential solutions for reducing it to levels that may deliver meaningful benefits for biodiversity.

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