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Multidisciplinary engagement for fencing research informs efficacy and rancher-to-researcher knowledge exchange

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Across much of the Western United States, recovery of large carnivore populations is creating new challenges for livestock producers. Reducing the risks of sharing the landscape with recovering wildlife populations is critical to private working lands, which play a vital role in securing future energy, water, food, and fiber for an ever-expanding human population. Fencing is an important mitigation practice that many ranchers, land managers, and conservationists implement to reduce carnivore-livestock conflict. While fencing strategies have been reviewed in the literature, research seldom incorporates knowledge from the people who utilize fencing the most (i.e., livestock producers). Incorporating producers and practitioners early in the process of producing scientific knowledge is proving to be a critical endeavor for enhancing knowledge exchange, better evaluation of the practice, and more realistic understanding of the costs and benefits. Here, we describe how our multidisciplinary effort of co-producing knowledge informs understanding of the effectiveness of various fencing designs and more importantly provides a better mechanism for transferring this knowledge between producers, researchers, and land managers. We explain the process underway and demonstrate that incorporating producers and practitioners from the onset allows research priorities and expected outcomes to be set collaboratively, gives transparency to the agricultural community of the research process, provides a critical lens to evaluate efficacy and functionality, and will inform the practicality of fencing as a conflict prevention tool. We discuss opportunities and challenges of this co-production process and how it can be applied to other realms of fencing and conflict prevention strategies.

KEYWORDS

nonlethal tools, carnivores, human-carnivore conflict, livestock, depredation, co-production, *Canis lupus*, *Ursus arctos*

Introduction

The reintroduction and recolonization of large carnivores like gray wolves (*Canis lupus*) and grizzly bears (*Ursus arctos*) in the Western United States has led to increasing interactions between these species and human livelihoods (Wilson et al., 2006; Mech, 2017). These interactions can result in conflicts, causing economic and emotional hardship for ranchers impacted by direct and indirect livestock losses (Muhly and Musiani, 2009), and lethal removal of carnivores. Livestock producers, natural resource managers, and conservationists are interested in finding and evaluating strategies that will prevent conflict (Bangs et al., 2006). Many strategies, including fencing, have been designed and evaluated by researchers and conservationists. Though significant efforts exist both in the US and worldwide, the design and evaluation process typically lacks producer input, opinion, and adoption information (Lozano et al., 2019; Bijoor et al., 2021; Bogezi et al., 2021). Many conflict prevention strategies do not integrate agricultural expertise and impact on production systems (Miller et al., 2016), nor local relevance and technical feasibility from communities (Bijoor et al., 2021). This trend continues despite a growing awareness that creating conflict mitigation tools without multi-stakeholder input is often detrimental to the real and perceived efficacy of each tool (Redpath et al., 2013; Wilkinson et al., 2021).

Integrating local knowledge is important to the success and durability of conservation initiatives and policy, including human-wildlife conflict prevention efforts (Lozano et al., 2019). Carrying out research on preventative strategies that integrates producers, practitioners, managers, and researchers can increase transparency and trust between groups, and lead to improved efficacy and adoption (Mishra et al., 2017; Volski et al., 2021). This is especially important in the field of human-carnivore conflict, where divergent perspectives of how large carnivores should be managed exacerbate tensions between interest groups (Bijoor et al., 2021; Venumière-Lefebvre et al., 2022). However, few studies on conflict management in the United States integrate local ecological knowledge (Lozano et al., 2019).

In recent years, co-production has emerged as a tool to develop knowledge in conjunction with local communities (Polk, 2015; Beier et al., 2017; Naugle et al., 2020). Beier et al. (2017) defined the process of co-production as "...collaboration

among managers, scientists, and other stakeholders, who, after identifying specific decisions to be informed by science, jointly define the scope and context of the problem, research questions, methods, and outputs, make scientific inferences, and develop strategies for the appropriate use of science". Co-production offers an opportunity to test unique management solutions that lead to durable working lands management and benefit nature. While conflict prevention is research-based, it also involves building deep collaborations and relationships with the stakeholders who have a primary and direct interest in the land. These relationships facilitate the flow of ideas that better inform the research and, ultimately, benefit nature and relationships among stakeholders on working lands.

Fencing, a common preventative strategy to reduce conflict with wildlife, would benefit from co-production and producer input. Fences can prevent livestock depredation and crop losses when properly installed, and are built in a variety of designs depending on environmental factors, target species, attractant, and production system. While a number of fencing designs have been tested and reported in the literature (e.g. Lance et al., 2010; Kesch et al., 2015; Young et al., 2015; Iliopoulos et al., 2019), producer input is seldom incorporated in research design.

In an attempt to improve the development and transfer of knowledge about fencing and other conflict mitigation techniques, we formed a group including livestock producers, natural resource managers, and researchers that has embarked on this process of co-production. Our group is part of the Conflict on Workinglands project, supported by a Conservation Innovation Grant from the Natural Resources Conservation Service (NRCS). For four months in 2021, we met bi-weekly to create research priorities and an evaluation plan to inform NRCS standards on fencing as a preventative strategy. Here, we explain the process underway and demonstrate how incorporating producers and practitioners from the onset allowed research priorities and expected outcomes to be set collaboratively, provided transparency to the agricultural community of the research process, created a critical lens to evaluate efficacy and functionality, and will eventually inform the practicality of fencing as a conflict prevention tool. Finally, we present benefits and tradeoffs of co-producing robust science through informed, on-the-ground experience from producers and practitioners. While our co-production process involved fencing, we believe this approach to be broadly applicable to conflict reduction strategies.

CIG co-production process

The Conflict on Workinglands Conservation Innovation Grant (CoW-CIG) from the NRCS was awarded in 2020 to a collaborative team that included people from non-profits, universities, ranches, and federal agencies. The project goal is to reduce the financial and social burden of expanding carnivore populations through innovation and evaluation of techniques that reduce human-wildlife conflict, leading to more resilient ranches and connected landscapes. In order to reduce the financial burden, we are seeking federal funding for conflict reduction strategies through NRCS Farm Bill programs, which would offset the resource constraints faced by many producers and cooperatives. Fencing is one of three focal conflict reduction practices being innovated through this project.

Through conversations between livestock producers and the CoW-CIG team, we recognized that while much research has been done to support livestock producers to find innovative and creative ways to minimize depredation, two principal hurdles exist. First, often the most promising and innovative tools are unknown to producers and managers alike because they are the least researched and communicated. Second, producers who implement new, innovative tools are often geographically separated from other producers confronted with the same challenges, limiting a key mechanism of information transfer. Communication and outreach of preventative strategies like fencing is crucial since producers are more likely to employ preventative strategies they learn from local trusted sources, such as neighbors (Volski et al., 2021), then state or federal employees outside their local communities (Young et al., 2018; Bonnie et al., 2020).

To help overcome these hurdles, the CoW-CIG team leveraged connections with practitioners, producers, and collaborative to develop a unique approach to studying fencing. In September of 2021, we formed a Technical Advisory Committee (TAC) comprised of members from a variety of disciplines (ranch and range management, biologists, researchers). We invited producers and practitioners that had expertise in fencing projects from around the Western United States and who agreed to actively engage in the co-production process.

Once the TAC team was established, the group met online bi-weekly to design research methodology to achieve the fencing-related goals. We met for one hour in the early morning to accommodate producer schedules and were mindful of the time limit. Organization of the online meetings was led by three team members from the CoW-CIG project who collectively set agendas. Initial conversations were facilitated by a researcher and centered around what types of fencing were useful; during these conversations the producer participants provided the majority of the information. We collectively set research priorities between all those involved, and took notes

visible on a shared screen to promote transparency. Notes were also distributed to all TAC members after each meeting. These discussions provided the basis for a graduate student research proposal, which was then shared with producers. Once a proposal was in place, the graduate student led meetings to obtain specific feedback on the research plan, with support from the two other CoW-CIG members. Producers provided feedback in real time and edits to the proposal were screen-shared to ensure transparency and accuracy of notes. Subsequent meetings were used to provide revised versions with producers' feedback incorporated. Once a research plan was established, meeting times were used to discuss methods for dissemination of the co-produced survey. We continued bi-weekly meeting for the first three months before changing to monthly meetings.

Priority setting with diverse desired outcomes

The co-production process with fencing research offered a unique method to prioritize research goals by integrating a diverse set of knowledge and experience. In our case, the process altered the scope of how we defined and will proceed with obtaining data on fencing. Prior to initiating a co-production process, our research team intended to focus on a small number of fencing types found in recent literature. However, instead of researching efficacy or seeking strong inference for a small number of fencing types, producers in the TAC meetings highlighted the need for flexibility in the type of fences deployed to meet site-specific needs. For example, producers from Montana and Oregon used different fencing designs to ward off the same carnivore species because of differences in topography and vegetation load.

Practitioners highlighted that fencing varied greatly depending on the size and type of operation, other wildlife using the landscape, husbandry practices, and the logistics of deploying any fence design. The TAC producers pointed out that, unlike some other conflict reduction strategies, many fence designs are not deployable immediately after a depredation because most fence designs are costly and time-consuming to install – although fladry and turbo-fladry (Lance et al., 2010) are the exception. This logistical pragmatism is not as frequently considered by researchers, as reported by producers and practitioners in the TAC.

The TAC members stressed that research should integrate not only how and where fences are effective, but also how to make funding opportunities for fencing projects more agile for producers. Producers that are facing the recolonization of large carnivores after years of their absence may need this information quickly and funding agencies or organizations will need to discern whether a design works and is worthwhile to cost share before depredations occur. Here, producers suggested

the importance of local level agency employees who know the reality of their production systems and who could have a significant role in shaping which fences are supported for funding.

Many projects, such as our own, tend to focus on management of one or two target wildlife species. However, producers in the Western United States must consider multiple competing human-wildlife conflicts that can affect production, as well as numerous conservation projects that want to collaborate with producers. For example, in Montana, conflicts can be from grizzly bears, wolves, mountain lions (*Puma concolor*), coyotes (*Canis latrans*), or ungulates such as elk (*Cervus canadensis*). A five-wire electric fence may be effective for reducing depredations from grizzly bears, but may not prevent elk from accessing hay in the same pasture. Producers and practitioners on the TAC emphasized the plurality of uses of fencing on an operation and the importance of considering all uses rather than solely carnivore deterrence, yet academic research often narrows the problem in order to find a singular solution. Ranchlands are complex and evolving, and resource needs are ever changing. Co-production creates a mechanism to incorporate the dynamic needs and ongoing considerations of producers into research plans.

Co-production can create awareness for priorities that were not detected by a single stakeholder group. An example of a priority that emerged from producers within the fencing TAC was for research and funding needs related to human safety concerns and fencing for grizzly bears. Funding agencies and conservationists frequently dedicate resources to fencing for agricultural attractants like calving areas, grain storage, or beehives, but do not consider that these attractants are often

found near human infrastructure. Our research was originally designed to analyze the effectiveness of fencing designs in preventing conflicts with agriculture or livestock, but the concern about human safety prioritized another measure of effectiveness and the need for fencing around farmstead or homestead areas. While this need was clear from the participants involved in our co-production process, this required additional coordination with agencies and broadening of research goals.

The co-production process requires flexibility in setting priorities that may have been outside of original objectives, funding guidelines, or that cannot be accomplished within the timeframe of the project. When setting priorities collectively, new ideas emerge, and research timelines and objectives can quickly shift from those that were originally outlined in the grant proposal. Changing priorities can be a challenge for practitioners who must balance organizational objectives and multiple grants and funding priorities. Researchers, meanwhile, often write grant objectives based on those likely to be accepted for publication in peer-reviewed scientific journals. The co-production process requires participants to rethink typical project structures while envisioning the research process within the scope of the initiative or the resource availability of the group (Figure 1). While this is required of all teams, the disparate timescale and differences in desired outcomes can create challenges in co-production.

In our project, we framed research goals for our current project with well-defined questions and immediate needs (Figure 1). However, as new ideas emerged that were within the scope of the current initiative but not of immediate need, we created a space to discuss them in the TAC while planning for

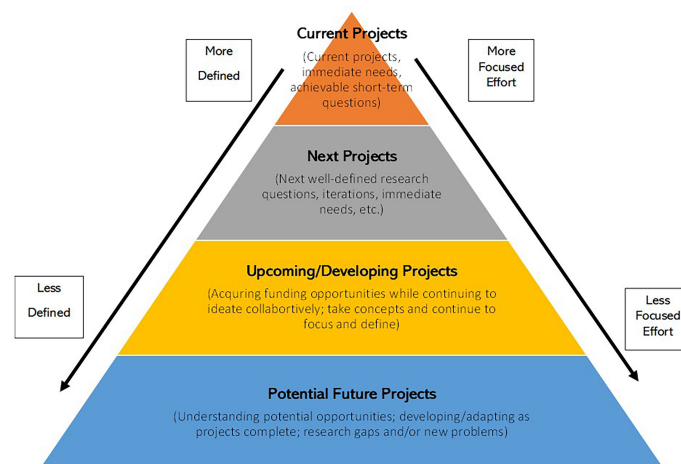


FIGURE 1

Research goals or questions are set by the co-production group according to this diagram, where well defined, short-term questions are addressed more immediately, but at the same time we develop new project ideas to address in the medium-term, and developing projects based on participant input that may fall outside of current funding or time limitations. Credit: Jared Beaver.

short-term projects (“Next Projects”). Some of those project ideas require additional funding and collaborations, which are yet to be defined (“Upcoming projects”). Lastly, after noting research gaps for fencing projects, we identified potential future opportunities that were not within the scope of our current initiative but could be developed later.

Holistic evaluation of efficacy and logistical considerations

Logistical considerations are also a fundamental contribution of the co-production process. Researchers involved in creating preventative strategies often view the issue from the perspective of the ecology of carnivores (Wilkinson et al., 2020). Carnivore ecology, however, is not the sole priority of most producers. Producers often prioritize installation cost, maintenance, forage quality, and water resources within fenced areas rather than how a carnivore will react to a linear feature on the landscape.

Knowledge from producers, developed over decades and often generations, is a keystone of practical research and implementation of strategies in livestock operations. A failure to understand the logistical subtleties of fencing designs for reducing human-wildlife conflict may result in missing the target of applied conservation. For example, in our process of co-production we initially set out to examine fencing for reducing depredation but learned from TAC conversations that it was important to also look at fencing for excluding herbivores because most ranchers are using the same fence designs for both objectives.

Since many conflict mitigation fencing strategies are designed outside of the agricultural community and with limited or no input from those communities, fencing types may be researched but not adopted, leading to a knowledge-action gap. This became apparent in our TAC meetings where producers reported that researchers often suggested fences that were not locally adapted or tested, leading to limited implementation. Moreover, researchers often do not have the administrative experience in land management that producers and practitioners possess. Cost share programs have certain restrictions on fencing, as does the construction of fences on public grazing allotments. Co-production gives a space to share functional and administrative considerations prior to commencing research.

Promoting adoption through transparency in research

Enhancing transparency in research is at the forefront of the TAC’s objectives because we believe this will help achieve our goal of reducing the financial and social burden of expanding

predator populations for impacted stakeholders. To achieve this objective, we found that an open dialogue about research procedures and producer needs was instrumental and required thoughtful listening and a willingness to adjust research plans according to producer suggestions. We began our first TAC meetings as an open dialogue about how producers were using fencing and how they thought fencing was being evaluated. We called this “the history of knowledge of fencing”, and it formed the basis for future conversations. Producers and practitioners then shared when, where, and why they applied each type of fencing. We then used meeting times to create a research plan together, again using an open dialogue format over video calls with on-screen note taking so that participants could see their comments in real time.

Having producers directly participate in research design lends credibility to later processes of adoption because ranchers are more likely to trust information produced by rancher engagement than by researchers alone (Wilmer et al., 2021). This process also responds directly to the needs of a customer service-based agency like NRCS, which looks to producers to identify resource needs and work within their existing operations. Our future steps include communicating research results through traditional and emerging forms of adult learning, such as podcasts, peer-learning workshops, and annual conferences.

Benefits and challenges of our approach

While this process has many benefits for our collective research and desired outcomes, it was not without challenges. Participant-reported benefits were mutual learning, transparency, and credibility to the research process. In general, benefits tended to be in the quality and applicability of the research, while challenges tended to be more logistic in nature.

Benefits

We found several benefits of co-producing research. The primary benefit was orienting our research progress towards our project goals. The CoW-CIG strives to provide value to producers, and also give NRCS information needed for conservation planning. Co-producing knowledge ensured that the project would be grounded in producer experience and needs.

The co-production process for fencing research gives transparency and credibility by having producers and practitioners participate as full partners (de Cremer and Dewitte, 2010), as reported by our participants. One technique we used to enhance transparency was screen-sharing all meeting notes during our TACs. All participants could see their

comments reflected in the notes, provide immediate edits and feedback of anything noted, and research plans were restructured during or immediately following meetings based on those comments. Co-production gives our future results credibility to the larger engagement process of the project by demonstrating that producer knowledge and conflict mitigation needs were incorporated into the research design process.

Project participants shared that mutual learning between producers, researchers, and practitioners is a crucial benefit of our method of co-producing fencing research. Participants were exposed to the reality of fencing designs and considerations across different scales. Some fences are implemented to reduce conflict for hobby farmers, others for orchard or apiary protection, and others for large cow-calf operations. Integrating actors that work within different types of agriculture fortified all participants' knowledge of the diversity of fencing types and challenged notions of the best types of fencing. From the researcher perspective, learning about the regulatory implications and obstacles to fencing on certain rangelands informed how we thought about adoption and the practicality of research for certain designs.

Fencing varies greatly due to topography, precipitation, livestock type, wildlife species, forage quality and grazing patterns of the operation. Producers in the fencing TAC reported learning from others about the conditions that dictate fencing designs from other areas. For researchers, the interactions that took place between producers to understand why certain fences were used also provided an important opportunity to learn more. Producers often knew what questions to ask about why a certain fence was used given their knowledge and experience in the intricacy of the subject matter, enhancing learning opportunities for all involved.

For practitioners and producers, the TAC meetings created an opportunity to experience the process of research and its constraints. During meetings, we discussed previously published research on fencing and preventative strategies that created the foundation for our study plans. We openly discussed the steps that we could face in our study in order to move it forward (graduate student committee meetings, Internal Review Board approval), as well as challenges like resources and relevance to the field.

Importantly, the co-production process has forced all parties involved to confront confirmation bias from their previous experience. Researchers on the project previously prioritized published research on strategies and carnivore ecology rather than considering experience on the ground, while producer participants prioritized personal and community experience with conflict prevention and carnivores. Each participants' perception of what works is contingent on their experience and our ability to make conservation practices work through adaptive implementation. The TAC creates a space for participants to share experience and learn from others, which enables us to question our own biases.

Challenges

Producing science collaboratively requires a much slower, more iterative process than traditional research. In our case, we held seven hour-long meetings for initial research design with the TAC, as well as prior consultations with ranchers. This time was in addition to the time typically allocated by researchers to read the literature and develop a proposal. We expect implementation of the research plan and interpretation of results be similarly time-consuming. This may pose a challenge to timelines of traditional research projects. In our project team, for example, there may be a mismatch in timing for researchers' progress, who are often beholden to the timeline of grant contracts. In our case study, producers and practitioners mentioned wanting immediate results in the short-term to reduce conflict, while simultaneously viewing conflict mitigation as a continuous, adaptive management process, given that their livelihoods and careers require involvement in the topic. Unlike researchers, they may not feel the pressure to produce research results in the short-term. Donor institutions may also require rapid progression, frequent reporting, and strict focus on proposed goals, putting additional pressure on the collaborative research process and limiting the full potential of this approach. For example, our grant cycle is for three years, and we are required to submit annual progress reports. Similarly, a traditional graduate student's path may not permit the flexibility in research planning, collection, and interpretation needed to conduct research in this manner. A student's funding is time-bound, often for 2-4 years, and the traditional process to complete a degree is linear, therefore major shifts in research priorities may not be possible. A lack of flexibility to reshape goals by either a student or funding agency may result in co-producer participants feeling unheard or undervalued.

When promoting a conflict prevention strategy, producers in our project mentioned that their peers often first express the sentiment that "that won't work here". Local culture, production techniques, and environmental factors are often cited as impediments to a fence design or other strategy being successful. A continuous challenge for those working in applied conservation is navigating between local needs, promoting adoption of proven solutions, and the need to demonstrate strong inference in research. We frequently discussed issues of variability of western rangelands across space and context in our TAC, yet it remains a challenge to all those working on conflict prevention and rangeland management broadly (Sayre, 2017).

Lastly, disparate time scales between producers, agency personnel, NGO practitioners, and researchers create a challenge for creating lasting relationships and integrating an adaptive management strategy into research of preventative strategies (Covey et al., 2021). Research projects are typically a

few years long and personnel from organizations may create strong relationships with producers but then move on to other opportunities. Meanwhile, producers are constantly working to mitigate conflict and improve their production system and planning is done on a longer timescale, often planning in terms of a decade or more. Drought planning, for example, is done at seven-to-ten-year time scales. Being able to temporally correlate community-based solutions to conflict and co-produced research is a constant challenge for those working in the field.

Conclusions

While the process that we engaged in was specifically to orient research for fencing as a tool to reduce wildlife conflicts, lessons learned from our experience are relevant to the emerging field of fence ecology as well as the development of other conflict prevention strategies. Conflict prevention suffers from a knowledge-action gap (Ruppert et al., 2021), whereby many practices that are researched have unknown adoption rates and why they are adopted is not well understood (Bogezi et al., 2021). The adoption of conflict prevention strategies can be stifled by tensions between interest groups with disparate views on how large carnivores should be managed, therefore the need to improve transparency and credibility to achieve shared outcomes is crucial to reducing the knowledge-action gap. Our project's belief, which has been endorsed by the larger community of producers we engage with, is that co-producing research alongside interest groups can promote appropriation of the research by those participating and change the messenger from researchers to producers.

For producer communities, academia and outside practitioners alike can be singular in their focus of the resource concern that fencing addresses, i.e., focusing on one species or family of species. Producers must navigate a complex, ever-changing landscape, as well as land management policies, and consider how one activity affects another resource concern. Researchers and practitioners should incorporate producers and stakeholders from the onset of study design to optimize benefits of fencing and reduce the time and resource burden of producers to implement and adjust fencing, as well as avoid unintended consequences for ecological communities.

While our case study focused on fencing, our approach can be broadly applied to researchers and interest groups working on human-wildlife conflict mitigation tools. Co-production offers an opportunity to collaboratively set priorities, adjust logistical considerations for relevant and enduring solutions, and may increase adoption within producer communities. Engaging with communities whose livelihoods depend on the resources affected by human-wildlife conflict will improve the lives of producers and wildlife alike.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

AF, JKY, SWB, JB, KK, MH, and RN conceived the technical advisory committees (TAC). AF, JKY, and MH coordinated TAC work, and CK, JSt, JSc, KE, and RT contributed vital knowledge to the co-production process and research design. MH led the writing of the manuscript, with critical input from all authors. All authors approved the submitted manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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