


Article

Exploring the Place of Animals and Human–Animal Relationships in Hydraulic Fracturing Discourse

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Abstract: Throughout human history, energy security has been a prominent concern. Historically, animals were used as energy providers and as companions and sentinels in mining operations. While animals are seldom used for these purposes in developed communities today, this legacy of use is likely to have far-reaching consequences for how animals and human–animal relationships are acknowledged in energy development. The US is currently experiencing an energy boom in the form of high volume horizontal drilling and hydraulic fracturing (HVHFF); because animals are the most at risk from this boom, this study uses a thorough content analysis of peer-reviewed HVHFF articles mentioning animals from 2012–2018 to assess how animals and human–animal relationships are discussed. Three dominant article theme classifications emerge: animal-focused articles, animal-observant articles, and animal sentinel articles. Across themes, articles seldom acknowledge the inherent value or the social and psychological importance of animals in human lives; instead, the focus is almost exclusively on the use of animals as sentinels for potential human health risks. Further, what is nearly absent from this body of literature is any social science research. Given that relationships with animals are an integral part of human existence, this study applies environmental justice principles, serving as a call to action for social science scholars to address the impacts of HVHFF on animals and human–animal relationships.

Keywords: hydraulic fracturing; animal studies; environmental sociology; environmental justice; companion animals; energy development

1. Introduction

On a small plot of land in Pennsylvania, Stacey Haney and Beth Voyles raised animals and children. In 2008, they combined their land in order to rent it to a Texas-based oil company that would use high volume horizontal drilling and hydraulic fracturing (HVHFF) to harvest natural gas. Both women thought it was a beneficial plan, providing them with additional income for their respective farms. However, in less than a year after drilling began, Haney’s animals, Hunter (dog), Boots (goat), and Boots’ offspring had all died. Similarly, Voyles lost her prized dog, Cummins, and at least 15 of Cummins’ offspring. Both families also experienced health repercussions (see, e.g., (Griswold 2011)). Their land sits above the Marcellus Shale Deposit, which is an American natural-gas field often used for HVHFF. HVHFF is a type of energy development that involves forcing high volumes of water, sand, and hundreds of hazardous chemicals into horizontally drilled wells to stimulate fractures and free up oil and gas stores that can then be recovered.

Over the last two decades, there has been increased debate and documentation of the impacts that HVHFF is having, and will have, on communities and individuals. Social scientists have been at the forefront of this discussion, detailing such things as the public perceptions of the social-environmental issues caused by HVHFF (Ladd 2013, 2018; Morrone et al. 2015; Vasi et al. 2015), local opposition and community division over HVHFF, differences in public and elite perceptions (Crowe et al. 2015), influence of familiarity with HVHFF on opinion (Willits et al. 2016), and HVHFF’s negative impacts

(Hauter 2016). What this literature tells us is that there is great division among the general public about the necessity of HVHMF and the impacts that it will have on individuals and communities. More importantly, the nuances in energy development discussions and perceptions are often location or community specific (see, e.g., Hula et al. 2017). Although, as the text above details, animals are an integral part of the HVHMF story, little attention has been paid to addressing the intersection of humans, animals, and HVHMF.

Outside of energy debates, social scientists are increasingly recognizing the value of including animals and human–animal relationships in social research, often discussing animals as a critically important but missing or overlooked variable (Carter and Charles 2018; Cudworth 2015; Peggs 2012; Tovey 2003). By bringing animals back into the conversation, social scientists have identified important connections that have led to significant social and policy changes. For instance, Fitzgerald and colleagues (Barrett et al. 2018; Fitzgerald 2007) argue that women in abusive relationships are often reluctant to leave their abusive partners because of fear that their companion animals may sustain increased violence or that domestic violence shelters will not accept them with a companion animal. This finding has led to an increase in domestic violence shelters accepting companion animals. In another area of research, Irvine (2009) documents the horrors of animal violence, neglect and abuse by authorities that kept local residents from leaving their homes during hurricane Katrina. This extended conversation led to the 2006 federal Pets Evacuation and Transportation Standards (PETS) Act, which directs state and local emergency plans to take pets and service animals into account in emergency planning. While these are only two examples of many, they demonstrate how understanding animals and human–animal relationships is becoming critical to understanding larger social issues. The current article is designed to continue this conversation, by looking at how animals (wild, agriculture and companion) and human–animal relationships are discussed and addressed in HVHMF research.

In 2012, Michelle Bamberger and Robert Oswald, a veterinarian and a pharmacologist, published a paper with the intention of starting a conversation about the impacts of HVHMF on animal populations and the associated connections to human health. Their article relies on 24 reported cases of animal harm. Opening a new avenue for discussion and making clear connections between animal and human well-being, the paper received widespread attention (see, e.g., Phillips 2012). Although their paper does not offer generalizable statements about the broad impacts of HVHMF on animals or the associated costs to human health, it does raise numerous questions about the use of animals as, what Whitley (2017) terms, unintentional sentinels in the expansion of HVHMF. This issue should be part of a larger discussion about the use of animals in energy development, a topic that has implications for both animal and human health, as well as for human–animal relationships more broadly.

Animals have a long and varied history in energy development that has often been overlooked (see, e.g., Whitley 2017, 2018). From antiquity until recent times, animals were used as energy providers. This dynamic only changed with technological innovation, at which point animals became intentional sentinels in mining operations and laboratory experiments, being used to assess the risks that mining toxins posed to humans. Though using animals as intentional sentinels fell out of favor in the 1960s, HVHMF's rapid expansion has reintroduced their use as harbingers of human risk. Researchers are monitoring (as unintentional sentinels) and once again conducting laboratory experiments on animals (as intentional sentinels) to assess the impacts of HVHMF toxin exposure, often with the objective of learning more about potential risks to human health.

Understanding the impact HVHMF has on animals and human–animal relationships is important for four key reasons. First, animals are inherently valuable; they contribute to ecosystem success and HVHMF will likely have individual and symbiotic impacts on their wellbeing. Second, although impacts on animals may signal potential risks to humans, they are also likely to impact human–animal relationships. For instance, in the example above, Haney and Voyles both experienced psychological trauma over the loss of their animals. Such trauma could be magnified in sensitive populations such as in senior populations living with pets (see, e.g., Himsworth and Rock 2013). In addition, this type

of trauma could have implications for animal ownership and rescue in high HVHMF regions. Third, the impact HVHMF has on animals may affect public perceptions of risk and behavior, as is the case with natural disasters, where harm to animals influences individuals' risk perceptions and behaviors (see, e.g., Irvine 2009). Additionally, HVHMF can impact veterinary services. Bamberger and Oswald (2012) argue that non-disclosure policies make treating animals exposed to HVHMF fluids a challenge. Along these lines, veterinarians in high HVHMF areas are likely coming into contact with greater numbers of exposure cases, changing how veterinary medicine is practiced.

Research on HVHMF is highly interdisciplinary and implications for animals are often embedded in ways that make it unclear whether these topics are being investigated. This study seeks to overcome this challenge by conducting a thorough content analysis of all peer-reviewed literature, published from 2012–2018, on HVHMF that mentions animals to provide a report on the state of the field that (1) determines how animals and human–animal relationships are featured in scientific literature on the impacts of HVHMF; (2) identifies themes among the suite of studies and; (3) assesses what additional research is needed as a call to action.

2. Background and Theory

Environmental Justice and the Place of Animals

The recognition of animals in energy development and the associated link to human lives is best situated within an environmental justice (EJ) framework. Historically, EJ has addressed the inequitable distribution of environmental services and burdens to vulnerable populations. Social scientists have long drawn on work from deviance studies, political economy and environmental justice to explain toxic exposure, consistently concluding that the poor and people of color have been victims of egregious ecological injustice (see, e.g., Mohai and Saha 2006, 2007). This literature is connected to a larger body of work that assesses how social and political inequalities are reinforced through access and distribution of the natural environment (see, e.g., Bullard 2005; Pellow 2017). Much of the literature is focused on the production, manipulation and unlawful disposal of toxic waste (see, e.g., Massari and Monzini 2004; Pearce and Tombs 2009; Ruggiero 1996). It should be noted that this body of literature within social science originated with a human emphasis. Specifically, Bullard and colleagues (Bullard 1994; Bullard and Wright 1993) were attempting to counter the environmental movement approach, which focused on impacts on the natural environment, by drawing attention to the impacts on vulnerable populations. At this time, the recognition of the interconnectedness between humans and animals was not fully realized, and remains an issue. EJ scholar David Pellow has been particularly interested in reincorporating animals into EJ conversations, especially around toxic exposure (Mohai et al. 2009; Pellow 2014, 2017). However, there remains a space for a deeper discussion not just about the impacts on wildlife populations, but about the shared impacts across species and the impact on human–animal relationships broadly.

Though there has been a concerted effort to apply concepts of EJ to human populations, nonhuman animals remain nearly absent from this discourse (Kopnina 2014). Kopnina (2014) argues that scholars are influenced by the “dominant neoliberal ideology of anthropocentrism” (p. 2) (see also, e.g., Callicott 1999; Catton and Dunlap 1978; Crist 2012; Kopnina 2012a, 2012b). The traditional tendency of social science to be anthropocentric has limited inquiry into animal–environment issues to discussions of the implications of these issues to humans, without regard for the inherent value of animal species (Beirne 2009; Nibert 2002). Kopnina (2014) clarifies this argument, suggesting that the “view of animals as culturally, socially or economically significant objects sees non-humans as facilitators of technological advancements (e.g., medical experiments or genetic manipulations), as an attribute of cultural practice (hunting or whaling) as the objects of economic interest (e.g., animal trade) symbolic ritual (e.g., animal sacrifice), or collateral damage (e.g., road kill or forest clearings)” (p. 4). In energy development, animals have not only been the facilitators of technological advancements, but they have

also served as sentinels, living indicators of risks posed to humans (Whitley 2017). In this way, the use and investigation of animals in energy development has been and remains anthropocentric.

An issue becomes an EJ concern when it is socially constructed as a problem (Taylor 2000). White (2013) argues that the nature of mining inherently creates EJ concerns because vulnerable populations always suffer. Several researchers have documented the potential risks HVHFF poses to human health through water contamination, fracking fluid spills, air pollution, etc. (Korfmacher et al. 2013; Kovats et al. 2014; Wattenberg et al. 2015). In doing so, these researchers have constructed a narrative about HVHFF as an EJ issue, with a focus on human health implications. What remains absent from this work, and the larger body of EJ literature, is any recognition of animals or human–animal relationships.

Schlosberg (2013) argues that, “one of the remaining border challenges of environmental justice theory is to make important connections with the environment itself . . . Yes, most of the discussion is about environmental bads and injustices to human beings, but the origins of environmental injustices are as much in the treatment of the non-human realm as in relations among human beings” (pp. 43–44). Although all mining practices have environmental impacts, the expansion of development, potential for chemical pollution, and hydrological alteration make HVHFF particularly concerning. Animals are likely to be the first affected in HVHFF development. Direct impacts on animals could have lasting effects on biodiversity and ecological services (Kiviat 2013). In particular, vulnerable animal populations such as those who have restricted ranges, are sensitive to environmental changes, or if endangered, may experience amplified effects. The potential risks are so concerning that HVHFF has been identified as a global conservation issue (Lloyd et al. 2005). Importantly, wildlife are not the only victims; the health and wellbeing of livestock and companion animals is also at risk (see, e.g., Bamberger and Oswald 2012, 2015), bringing up questions about the rights of animals to have equitable access to environmental services such as clean water and air. This study seeks to demonstrate that HVHFF is not just an EJ issue for humans, but that animals and human–animal relationships should be considered as well. The study that follows uses a content analysis approach to evaluate the extent to which animals are considered in HVHFF discussions within peer reviewed journal articles. In doing so, it provides tangible evidence in support of Schlosberg (2013) assertion that we need more discussions of animals as victims in environmental justice narratives.

3. Data

All peer-reviewed articles published between 2012 and 2018 that are about HVHFF and mention animals were examined. To ensure that the analysis is inclusive, data collection was conducted using three steps. The process began with Bamberger and Oswald’s 2012 paper, described in the introduction, as it is considered the seminal article exploring the potential impacts HVHFF has on animals. All citations within the articles citing Bamberger and Oswald (2012) were analyzed. Next, all peer-reviewed articles citing Bamberger and Oswald (2012) were reviewed. Finally, the resulting list was cross-referenced with a search in the Web of Science database looking for peer-reviewed articles featuring hydraulic fracturing (using key terms: hydraulic fracturing, fracking, unconventional energy development, and natural gas development) and animals (using key terms: animals, ecosystems, fisheries, wildlife, livestock, agriculture, invertebrates, biodiversity, fauna, and mammals). A total of 118 articles were identified.

4. Method

A content analysis approach was applied, which is a widely used technique to identify and describe patterns in textual data. All text was coded in Nvivo 11.4. Nvivo is a qualitative data analysis software tool that allows for the coding, sorting, querying and sharing of unstructured data. Line data were coded into nodes and then consolidated into categorical themes. First, all articles were reviewed to give the researcher a feel for these data. Second, abstracts were coded for the presence of animal terms. For instance, if animals were featured in the abstract it was assumed that the animals were

a central focus of the article. If animals were not featured in the abstract, it was assumed that they had little importance in the article or were simply a line reference. Additional nodes were identified to code the central themes of each abstract, regardless of animal inclusion. Abstracts were chosen as the first level of analysis, because they provide summaries of articles and are likely the first thing people assess before reading an entire article. Third, a line-by-line review of all articles was done to assess when and how animals were discussed. Finally, a second coder was asked to independently code all text. Inconsistencies between the two coders were discussed until consensus was reached. Limited inconsistencies were found, as nodes relied on the presence of specific words related to animals or other subcategories of environmental and social impacts. Three major themes emerged. These themes and the associated subthemes are discussed below.

5. Results and Discussion

The analysis aims to clarify how animals and human–animal relationships are included or excluded in scientific discussion on HVHFF. Of the 118 articles analyzed, only 44 (37%) mention animals in the abstract. Across all articles, three dominant themes emerged. First, 25 (21%) articles directly mention animals or ecosystems in the abstract and focus on the impacts HVHFF has on a specific animal, group, or species. These 25 articles are referred to as “animal-focused” articles. Second, 23 (20%) articles review the impacts of HVHFF and mention animals or ecosystems in the abstract but do not exclusively focus on animals, including non-animal impacts as well. These are referred to as “animal-observant” articles. Finally, the majority of articles (70 articles, 59%) did not mention animals in the abstract but cited the [Bamberger and Oswald \(2012\)](#) article to support a claim about the impacts of HVHFF on humans. These articles are referred to as “animal-sentinel” articles. Within each theme, subthemes emerged.

5.1. Animal-Focused Articles

The articles within this group either provide a general overview of the impacts of HVHFF on ecosystems or focus on specific impacts on a species. General overviews of ecosystem impacts consistently conclude that freshwater organisms, species sensitive to land fragmentation, and animals with restricted ranges are the most at risk ([Gillen and Kiviat 2012](#); [Kiviat 2013](#)). In these articles, animals are the focal point and the research examines how HVHFF affects them. For instance, research suggests that the redbfin darter, a fish that is endangered in some US states, is vulnerable to silt input in streams ([Stearman et al. 2015](#)); native brook trout conservation and restoration are at risk ([Weltman-Fahs and Taylor 2013](#)), as are Zebra fish and their habitats ([Folkerts et al. 2017](#); [He et al. 2018](#)); migrating fracturing fluids may cause adverse effects in rainbow trout ([He et al. 2016](#); [Folkerts et al. 2017](#)); fish exposed to waters contaminated with fracking fluids show signs of general stress and higher incidences of gill lesions compared to unexposed fish ([Papoulias and Velasco 2013](#)); and a positive correlation exists between the presence of HVHFF wells and mercury concentrations in crayfish, and other predatory macro invertebrates and brook trout ([Grant et al. 2015](#); [Blewett et al. 2017a](#); [Blewett et al. 2017b](#)). In addition, non-aquatic animals may also be affected by water contamination. For instance, metal accumulation in riparian songbirds is higher in heavy HVHFF areas compared to those residing in areas without HVHFF ([Latta et al. 2015](#)) and the leopard frog may be particularly vulnerable ([Funk and Stabenau 2017](#)).

A handful of articles that focus on specific species demonstrate that land fragmentation contributes to animals avoiding roadways, which isolates them to smaller areas of land, a trend documented in grassland bird species ([Thompson et al. 2015](#)), salamanders ([Brand et al. 2014](#)), mule deer ([Lendrum et al. 2012](#)), and river otters ([Godwin et al. 2015](#)). Although land fragmentation is not likely to have a big impact on livestock and companion animals, range restrictions might; despite this possibility, studies of the impacts of HVHFF on livestock and companion animals are scarce. For instance, in the only identified study on livestock, [Finkel et al. \(2013b\)](#) assess how HVHFF affects cow and milk production over a five-year period, finding that production decreased as

HVHHF development increased. Similarly, beyond the original [Bamberger and Oswald \(2012\)](#) article, only three studies report on the impacts on companion animals and human–animal relationships. First, [Slizovskiy et al. \(2015\)](#) use a community health survey with questions about companion and livestock health to assess how the distance to the nearest HVHHF well relates to reported human and animal health. They find that the reported health of dogs is significantly lower for people living within 1 km of a gas well compared to those living farther away. Second, a follow-up article by [Bamberger and Oswald \(2015\)](#) demonstrates that the negative health impacts decrease for families (including animals) moving away from HVHHF areas, while health impacts remain the same or increase for those continuing to reside in high volume drilling areas. Finally, in conducting interviews among Pennsylvania residents with a focus on women, [McHenry \(2017\)](#) finds that people are particularly concerned with how hydraulic fracturing impacts their family pets.

Assessing the articles in this thematic category leads to three broad conclusions. First, although these articles focus almost exclusively on animals and tend to argue for the inherent value of animals, they largely justify studying impacts on animals by connecting them to human systems. For example, this group of studies generally mentions human health or the preservation of ecosystem services in the conclusion as a justification for focusing exclusively or almost exclusively on animals. Second, there is limited social science research in this body of literature. Only one study, [McHenry \(2017\)](#), is from a social science perspective. Specifically, there is no broad assessment of how hydraulic fracturing is impacting animals or human–animal relationships; there are only assessments of the impacts on animals that may signal potential risks to humans. Finally, and perhaps most surprisingly, the lengthy history of testing mining toxins on animals to assess and mitigate human health risks is alive and well in research with a few studies reporting on the use of laboratory mice to assess toxin exposure extremes ([Kassotis et al. 2015](#); [Kassotis et al. 2016a](#)). This is interesting because it goes beyond the assumption that animals are simply serving as unintentional sentinels in HVHHF development. Instead, this evidence suggests that animals are also serving as intentional sentinels.

5.2. Animal-Observant Articles

The articles in this group (N = 23) mention animals in the context of other HVHHF risks and do not focus on a specific animal or species. In most cases, these articles focus on environmental damage or contamination. Terms such as “animals” and “ecosystems” are widely used. Unlike the previous category, the focus of these articles is on the broad effects, which happen to include impacts on animals. So, for instance, in thinking about water contamination, the author might mention all of the potential impacts, where in the previous category the analysis or discussion would be on the impacts HVHHF has on a particular species or group of animals. There are no social science articles in this group.

The majority of articles in this thematic category emphasize freshwater ecosystems as their animal focal point. This is not surprising, as these articles cite many of the “Animal-Focused Articles” listed above as supporting evidence. For instance, studies show that chemicals used in hydraulic fracturing pose a risk to ecosystems ([Entrekin et al. 2018](#); [He et al. 2017](#); [Loh and Loh 2016](#); [Vandecasteele et al. 2015](#); [Yao et al. 2015](#)). Specifically, [Kassotis et al. \(2016b\)](#) find that injection well disposal sites reveal elevated levels of toxins that could disrupt reproduction and development in aquatic animals (see, e.g., [Elliott et al. 2017](#)). Additionally, HVHHF leads to increases in pH in area streams ([Lutz and Grant 2016](#)), and water contamination can enter the food chain impacting cattle, poultry, and aquatic life ([Kun et al. 2014](#); [Pothukuchi et al. 2018](#)). Notice that in all of these cases, animals are mentioned, but they are mentioned in the context of environmental contamination where the focal point is on contamination and not on animals.

Instead of centering on a particular environmental impact, some articles provide general overviews of environmental risks ([Brittingham et al. 2014](#); [Burton et al. 2014](#); [Lave and Lutz 2014](#); [Souther et al. 2014](#)) or information about regulatory processes ([Ralston and Kalmbach 2018](#)). For instance, in an analysis of land use and shale development, [Moran et al. \(2015\)](#) assert that, “shale gas development will likely have substantial negative impact effects on forested habitats and

the organisms that depend upon them” (p. 1276) and [Abrahams et al. \(2015\)](#) note, “well pads, access roads, and gathering lines fragment forestland resulting in irreversible alterations to the forest ecosystem” (p. 153). Similarly, in a paper looking at how Saskatchewan is responding to hydraulic fracturing, the authors note that people are concerned about impacts on animals and ecosystems ([Olive and Valentine 2018](#)).

Finally, a key component of articles within this theme is the effort to position research as important for supporting human systems. For example, multiple scholars argue that failing to understand threats to ecosystems and provide proper regulatory mechanisms are likely to contribute to ecosystem loss, which has implications for human health ([Allred et al. 2015](#); [Bamberger and Oswald 2014](#); [Down et al. 2013](#); [Finkel et al. 2013a](#); [Finkel et al. 2013b](#); [Jones et al. 2015](#); [Kassotis et al. 2016a](#); [Kassotis et al. 2016b](#); [Robbins 2013](#); [Ticleanu et al. 2014](#)). Three important takeaways emerge from this group. First, articles mention animals as being impacted by HVHFF, but do not focus on a specific group or species. Second, unlike the articles in the animal-focused group, these articles center on making a connection between animal (and environmental) impacts and human health, paying less attention to the inherent value of nature or animals. Finally, there are no social science articles.

5.3. Animal Sentinel Articles

Animal sentinel articles do not mention animals or ecosystems in the abstract (n = 70). Overall, this group uses the [Bamberger and Oswald \(2012\)](#) article to support discussions on one of five key HVHFF subthemes: public health concerns (n = 24 or 35% of animal sentinel articles), environmental impacts (n = 19 or 27% of animal sentinel articles), community impacts and public perceptions (n = 16 or 23% of animal sentinel articles), policy (n = 7 or 10% of animal sentinel articles), and general reviews of broad impacts (n = 4 or 6% of animal sentinel articles).

First, the largest group of articles in this theme emphasizes public health concerns (n = 24). These articles discuss the impacts of HVHFF on either broad public health categories (see, e.g., [Adekola et al. 2016](#); [Boyle et al. 2016](#); [Ferrar et al. 2013](#); [Finkel and Hays 2013](#); [Goldstein and Kriesky 2012](#); [Korfmacher et al. 2013](#); [Mitka 2012](#); [Penning et al. 2014](#); [Perry 2013](#); [Rabinowitz et al. 2015](#); [Rafferty and Limonik 2013](#); [Redmond 2014](#); [Saber 2013](#); [Saber et al. 2014](#); [Saunders et al. 2016](#); [Shonkoff et al. 2014](#); [Steinzor et al. 2013](#); [Tuller 2015](#); [Werner et al. 2015](#); [Willems et al. 2016](#)) or specifically to infant or reproductive and developmental health ([Kassotis et al. 2015](#); [Ma et al. 2016](#); [Payne et al. 2014](#); [Webb et al. 2014](#)). If mentioned, animals are only used to situate the potential and realized impacts on human health or to assert that more research is needed (see, e.g., [Ma et al. 2016](#)). For instance, in a review of HVHFF health impacts, [Shonkoff et al. \(2014\)](#) cite [Bamberger and Oswald \(2012\)](#) after discussing fracking fluid containment by noting “These containment ponds are often, but not always, lined to protect against leakage; however, case studies have documented reported ruptures to these liners that may have led to water and soil contamination and contributed to fish and livestock deaths ([Bamberger and Oswald 2012](#), p. 793)”. This is the only reference to animals in the article and is simply used to support the thesis that additional epidemiological studies are needed to evaluate risks to human health.

Second, a group of studies within this theme speak to environmental impacts (n = 19). Two articles review broad environmental impacts ([Arent et al. 2015](#); [Reible et al. 2016](#)), while the remaining 17 focus on air quality or water use and contamination. For instance, HVHFF is known to have broad impacts on air quality ([Bai et al. 2016](#); [Brown et al. 2014](#); [Brown et al. 2015](#); [Bunch et al. 2014](#); [Colborn et al. 2012](#); [Field et al. 2014](#); [Moore et al. 2014](#)). Similar to the health impacts subtheme, this group minimally mentions animals in the text or uses [Bamberger and Oswald \(2012\)](#) as a general nod to potential impacts on human health. For instance, [Bunch et al. \(2014\)](#) do not mention animals at all, but cite the article to show that few “studies have focused on atmospheric emissions and, in particular, on the potential impacts of such emissions on human health” (p. 833). A second group of environmental impact articles speak to issues of water quality. For instance, these articles discuss the chemical composition of water and wastewater disposal wells near HVHFF sites ([Kassotis et al. 2013](#);

Rich and Crosby 2013; Zhai et al. 2016), wastewater spills and water contamination (Koh et al. 2016; Konkel 2016; Penningroth et al. 2013; Sang et al. 2014), and broad debates about water use and contamination (Ernststoff and Ellis 2013). Overall, animals are excluded or only mentioned in superficial ways.

Third, there are 16 community impacts and public perception articles. This subtheme is the only one to include social science articles. In these articles, HVHHF is evaluated in terms of public perceptions (Choma et al. 2016; Dokshin 2016; Israel et al. 2015; Morrone et al. 2015; Powers et al. 2015), community disorder and boomtown issues (Jerolmack and Berman 2016; Ruddell and Ortiz 2014), changes in traffic (Graham et al. 2015), economic impacts (Barth 2013; Muresan and Ivan 2015), broad or case-specific social impacts (Garvie et al. 2014; Perry 2012), and environmental justice and human rights (see, e.g., Clough and Bell 2016; Fry et al. 2015; Johnston et al. 2016; Short et al. 2015). Once again, these articles give little attention to the impacts of HVHHF on animals. Specifically, animals and human–animal relationships are not mentioned in survey analyses or in discussions about community impacts broadly. What is most interesting about this collection is that even among the environmental justice focused articles, animals are non-existent. For instance, in discussing the connection between human rights and HVHHF, Short et al. (2015) cite the Bamberger and Oswald (2012) article to suggest that “Land can also be impacted through water, air or soil pollution as we have seen above, along with damage to livestock, vegetation and wildlife” (p. 15), but give no designated attention to animals or human–animal relationships in their analysis. Once again, this group mentions animals or ecosystems to support the discussion of potential risks to humans.

Fourth, some articles focus on policy initiatives and debates (n = 7). Within this group, articles focus on policies and practices in monitoring and management (Centner and Eberhart 2015; Wylie and Albright 2014), local distance ordinances and management (Centner and Kostandini 2015; Fry 2013), political debates and public policy (Bamberger and Oswald 2013; Beebeejaun 2013), and national acts and orders (Geltman et al. 2016). As with the others, articles in this subtheme either do not specifically mention animals or only mention them to support a claim about human or environmental wellbeing. The single exception to this is Bamberger and Oswald’s 2015 follow up article to their original 2012 publication, in which they deliberately discuss the impact of HVHHF on livestock, mentioning that livestock remaining in HVHHF areas recovered from reproductive distress initially seen on the onset of production, but developed long-term respiratory issues.

Finally, a small group of articles provide general overviews of the impacts of HVHHF, addressing both environmental and social concerns (n = 4) (see, e.g., Esterhuysen et al. 2016; Hays et al. 2015; Stephenson 2016; Wang et al. 2014). Once again, this group cites Bamberger and Oswald (2012) without mentioning animals. For instance, Stephenson (2016) notes, “concerns over additives used in hydraulic fracturing fluid mainly center on them reaching the environment from spills at the surface or in transport, from illegal dumping of wastewater, or from damage to the liners of wastewater impoundment dams” (p. 8), which is followed with the Bamberger and Oswald citation. The article does not specifically mention animals. By evaluating articles in the animal sentinel theme, two conclusions emerge. First, the majority of articles that cite the Bamberger and Oswald (2012) article only use the citation to situate research on the impacts of HVHHF on humans, paying little or no attention to the direct impacts that HVHHF has on animals and human–animal relationships. Second, it is clear that social science, including environmental justice scholars, have neglected this area of research.

6. Conclusions

As HVHHF continues to expand, numerous environmental and social impacts are being acknowledged; however, the place of animals in this discourse remains limited, especially among social scientists (see, e.g., Whitley 2017, 2018). Assessing the impacts of HVHHF on animals and human–animal relationships is particularly important because animals have inherent value, they contribute to ecosystem viability, and there will likely be shared impacts between humans and animals. Studies that mention animals or cite animal-related research in the context of HVHHF

can be divided into three thematic categories: animal-focused, animal-observant, and animal sentinel articles. Animal-focused articles assess the risks of HVHHF on animal life, often on a particular species. Animal-observant articles mention impacts of HVHHF on animals, but in the context of other issues or themes. Articles in this group do not focus on animals, but impacts on animals are acknowledged. Finally, the majority of articles cite animal-focused articles to make a claim about the impacts HVHHF has on something or some community other than animals. Social science work is nearly absent from all categories. Specifically, there is no focused discussion of human–animal relationships in the face of HVHHF or of how the impacts of HVHHF on animals influence social and community dynamics. The clear gap in literature mimics the assertions that social science has neglected the natural environment and, in this case, animals as an important topic of analysis for social life. What this analysis shows is that there are many ways that social scientists can engage with broadly understanding the intersection between humans, animals and energy development, and HVHHF in particular.

While some studies acknowledge the inherent value of animals (studies in the animal-focused theme), most cite risks to animals as a means of understanding the potential risks to human health. This is perhaps unsurprising, given humans' lengthy history of using animals as intentional and unintentional sentinels in energy development and the EJ focus on human lives. For instance, scholars have often argued that the tracking and monitoring of sentinel species is an important technique to assess human health risks (McCarthy et al. 1990; Rabinowitz et al. 2009). A benefit of observing animals in HVHHF areas is that this approach does not isolate and expose animals to toxic chemicals in a laboratory (Rabinowitz et al. 2010). However, animals are only tracked and monitored when exposure to humans has occurred or is expected to occur. As a consequence, such work may negate the inherent value of animals, since tracking and monitoring is unlikely to occur when there is no concern over human health risks. Tracking may also involve the capture and tracking of animals, which could put stress on a particular animal or population. In many ways, animals observed in this form have become the new "canaries in the coal mines" as unintentional sentinels.

Importantly, animals continue to be used in laboratory settings to test energy development chemicals. So, not only are animals being tracked as unintentional sentinels in their natural environments to signal human health risks, but are also being experimented on in laboratory environments to explore the toxicity of HVHHF fluids. There is growing research that suggests that experimentation on animals is often flawed, misleading, and wasteful (see, e.g., Arluke 2010; Arluke and Michael 2007; Eisenman 2016). Because of this, many scholars and industries have called for alternatives to animal-based experimentation (see, e.g., Khilnani and Khilnani 2016; Kumar et al. 2017). Although, field observation can make isolating the effects of HVHHF difficult, motivating experiments on animals, several of the studies mentioned above have used field experimentation to document impacts effectively with minimal risk to animals. Many of the field experiments have a dual human and animal focus. This means that the researchers are interested in monitoring human risk as well as supporting biodiversity. Although there has been some work to assert that animals are sentinels in HVHHF expansion, the use of animals in laboratory experiments to document the potential effects of HVHHF toxins has not been addressed. It is unlikely that many, even within Animal Rights circles, are aware of the laboratory testing conducted on animals to gain insight into the harmful effects of HVHHF chemicals. Such information may be particularly important in aligning animal rights activists and fracktivists movements (a range of people from those who strongly oppose hydraulic fracturing to those who support extensive policy and practice reform before expansion is allowed to continue). Scholars should consider looking into the use of animals in laboratory environments to get a better understanding of how widespread this practice is across energy platforms and how this practice has increased or decreased over time.

Ultimately, this content analysis of literature highlights numerous gaps in assessing the impact HVHHF has on animals and human–animal relationships. Not only are more geographically- and species-diverse studies needed to assess vulnerability and reliance by all scientists, but social scientists

in particular need to assess the effects HVHMF has on human–animal relationships. In particular, environmental justice scholars need to include animals and human–animal relationships in their analyses of the impacts of HVHMF. Several reports suggest that people and animals may suffer shared health problems because of HVHMF. Scholars should investigate what this shared suffering means for companion animal ownership, loss, veterinary care, self-identity, and family life as well as exploring the social and psychological implications. In addition, scholars should investigate questions such as how rescue organizations are responding to HVHMF, especially in high development areas, and how people in HVHMF areas are working to keep their animals and themselves safe. Beyond this, research suggests that boomtowns may fuel social disorder, which can lead to increases in violence. Scholars should explore how animals fit into this equation and whether there is increased violence against animals in these communities.

Across thematic categories, human health remains a dominant subtheme. Most studies, regardless of their central focus, conclude by discussing the potential or realized risks of HVHMF to human health, but not to human–animal relationships. Despite this, the reality is that the impacts of HVHMF on animals will likely go beyond shared health concerns. As with the example in the beginning, seeing companion or agriculture animals in distress can increase human stress, something that has been documented in other studies, particularly in studies assessing the impacts of companion animal death on human wellbeing. Scholars should take inventory of how individuals in heavy HVHMF areas are negotiating these relationships and if the impacts on animals are having negative impacts on human mental health.

Finally, human relationships with animals may alter how people respond to HVHMF risks (see, e.g., [Whitley 2017](#)). There is some work that has also highlighted this claim, but has not evaluated this question extensively (see, e.g., [McHenry 2017](#); [Olive and Valentine 2018](#)). More should be done to assess how our relationships with animals inform our understanding of, and response to, HVHMF risks. Identity and value structures are known to play a role in how people think about various environmental issues (see, e.g., [Dietz and Whitley 2018b](#)) and may also be important in how people think about the intersection of energy development, humans and animals. More attention should also be placed on looking at how racially diverse communities consider these issues in order to challenge the assumption that communities of color do not care about environmental issues or animals (see, e.g., [Dietz and Whitley 2018a](#)). Further, research shows that framing HVHMF in terms of impacts on animals may be powerful in generating greater concern (see, e.g., [Whitley 2017](#)). There is a wealth of studies that document the importance of how environmental issues are framed and how animal framing, such as the iconic polar bear for climate change, can drive public perception ([Whitley and Kalof 2014](#); [Kalof et al. 2017](#)). Ultimately, this analysis suggests that there is much work to be done to centralize animals and human–animal relationships as essential in assessing the impacts of HVHMF and that this work should be done by social scientists from an environmental justice perspective, supporting [Schlosberg \(2013\)](#) assertion that we need more discussions of animals as victims in environmental justice narratives.

There are limitations to this study. The focus on peer-reviewed published articles could be considered a limitation. There are several non-peer-reviewed sources that address the impacts of HVHMF on animals ([DeDonder et al. 2015](#); [Hill 2013](#); [National Parks Conservation Association 2013](#)). Further, there may be additional social and natural science HVHMF articles that discuss animals, but that were not considered as contributing to the dominant discussion because they did not cite the [Bamberger and Oswald \(2012\)](#) article and could not be found when searching for animal key terms. Finally, because of the historical exclusion of the natural environment and animals from social science literature, there may be social science scholars working in this area that have yet to publish their work. If this is the case, broad searches of all materials including conference papers, dissertations, etc., should reveal additional sources that would not have been considered for this analysis but could be evaluated in the future.

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