Public views about gene editing wildlife for conservation

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Article Impact statement

Study results begin to lay groundwork for conservation biologists to organize constructive public deliberations about gene editing wildlife.

Abstract: Developments in CRISPR-based gene-editing technologies have generated a growing number of proposals to gene edit populations of wildlife to meet conservation goals. These include proposals to use wildlife genome editing as a response to the spread of invasive species and other threats to biodiversity. As these proposals attract greater attention, controversies have emerged among scientists and stakeholder groups over potential consequences and ethical implications. Stakeholders on both sides of debates acknowledge that responsible governance cannot be developed without consulting broader publics. Yet little effort has been made to systematically assess public understandings and beliefs in relation to this new area of applied genetic engineering. In this study, we analyze the results of a survey of American adults (n = 1,600) to examine concerns about gene editing wildlife and how those concerns are shaped by cultural dispositions toward science and beliefs about the appropriateness of intervening into nature at the genetic level. On average, people perceived more risk than benefit in using these tools. Large majorities also agreed that gene editing wildlife could be easily used for the wrong purposes. When evaluating the moral acceptability of gene editing wildlife, people evaluate applications to improve survival in endangered wildlife as more morally acceptable than applications to reduce or eliminate a wildlife population. People who tend to more strongly believe in the authority of scientific knowledge expressed more favorable views of the benefits, risks, and moral acceptability of gene editing wildlife. On the other hand, people who tended to think gene editing wildlife inappropriately intervenes in nature expressed more concern about risks and moral acceptability and were more skeptical of the benefits.

Introduction

The development of advanced gene-editing tools has generated a growing number of proposals to alter wildlife genomes as a response to the spread of invasive species and other threats to biodiversity such as disease, low genetic diversity, and climate change (e.g. Corlett 2017; Piaggio et al. 2017; Novak et al. 2018). There is widespread agreement among scientists, non-profit stakeholders, and scientific advisory institutions that consulting public stakeholders early and often is critical to making responsible decisions about when or whether advanced gene-editing tools should be used to address biodiversity challenges (e.g. National Academies of Sciences Engineering and Medicine 2016; Te Pareake Mead et al. 2017; International Union for Conservation of Nature 2018). Yet, to date there has been little systematic effort to assess how various publics may respond. An assessment of public opinion provides an important first step toward extending deliberations about gene editing wildlife to account for public understandings, values, and concerns. In this study we provide a descriptive overview of U.S. public views of gene editing wildlife for conservation. We also conduct multivariate analyses to identify factors related to perceptions of the benefits, risks, and moral acceptability of gene editing wildlife.

Using advanced gene-editing technologies for conservation

Humans have long used genome-altering technologies to manipulate organisms for research and agriculture. However, manipulating genomes across wild populations remained impractical before the discovery of the gene-editing tool CRISPR-Cas9 (Esvelt et al. 2014; Champer et al. 2016). CRISPR-Cas9 (hereafter CRISPR) is faster, more affordable, and easier to use than earlier genome-altering technologies (Doudna & Charpentier 2014). Perhaps most importantly, CRISPR has given a major boost to the development of gene drives, which can be

used to sweep a genetically altered trait through a wildlife population much faster than it could spread through normal genetic inheritance (Esvelt et al. 2014; Kyrou et al. 2018).

A growing number of conservation biologists are therefore considering gene editing as an option to address problems that have not been solved by traditional conservation practices (Corlett 2017; Piaggio et al. 2017). Meetings have been convened to foster greater dialogue between conservationists and synthetic biologists developing gene-editing wildlife tools (Redford et al. 2013; Redford et al. 2014). But some biologists and others in the conservation community remain wary of gene editing wildlife proposals and a few have come out in opposition (Webber et al. 2015; Civil Society Working Group on Gene Drives 2016).

Benefits, risks, moral acceptability, and accountability

The unprecedented power and potential of newly discovered gene-editing tools have generated both excitement and alarm. Optimism about the promise of these tools for addressing conservation problems is tempered with caveats about risks (Esvelt et al. 2014; Webber et al. 2015; NASEM, 2016). At this early stage of development, outcomes remain largely hypothetical and highly uncertain (NASEM, 2016). At the same time, urgent extinction threats create strong motivation to rapidly adopt new and sometimes radical conservation approaches (Redford et al. 2014; Corlett 2017).

In addition to raising questions about relative benefits and risks, genetic engineering often generates considerable ethical debate (Frewer et al. 1997; Verhoog 2003; Cooley & Goreham 2004). Proposals to gene edit wildlife add a unique dimension to questions about whether genetic engineering crosses moral boundaries. As a conservation tool, gene editing could be used to "do bad things to unwanted species" or "do good things to wanted species" (Corlett 2017). For example, gene editing could be used to decrease or eliminate an invasive animal or plant population by introducing a trait to reduce survival fitness or disrupt reproduction. More ambitious applications could include improving survival

fitness in threatened and endangered species by increasing genetic diversity or accelerating evolutionary adaptation to invasive pathogens or climate change (Thomas et al. 2013; Piaggio et al. 2017).

Views about the moral acceptability of gene editing wildlife for conservation may therefore hinge, in part, on whether an application is designed to decrease or eliminate a wildlife population, or to improve survival in endangered wildlife. These two types of applications might also raise unique concerns about accountability. Is there greater potential for one of these types of applications to be used for the wrong purposes? The first part of this study focused on three broad research questions about American views of gene editing wildlife:

RQ1) Will respondents perceive the benefits as outweighing the risks?

RQ2) Will respondents perceive applications to decrease or eliminate environmentally problematic wildlife populations as less morally acceptable than applications to improve survival in endangered wildlife?

RQ3) Will respondents perceive applications to decrease or eliminate environmentally problematic wildlife populations as more likely to be used for the wrong purposes than applications to improve survival in endangered wildlife?

In the second part of this study, we examine how individual-level factors predict views about wildlife gene editing wildlife. In particular we test whether perceptions of the benefits, risks, and moral acceptability of gene-editing wildlife are predicted by individuals' belief in the "authority of scientific knowledge," "messing-with-nature" beliefs, and attention to science news.

Belief in the authority of scientific knowledge

A growing body of research highlights the important role cultural dispositions toward science play in shaping the way citizens think about complex scientific issues (Brossard & Nisbet 2007; Kim et al. 2014; Akin et al. 2017). In particular, systems of belief that privilege science as having epistemic and social authority tend to correlate with positive attitudes toward scientific issues. For example, individuals who are more deferential toward scientific authority tend to have fewer reservations about the impacts of science, and to support emerging technologies even when they involve hard to quantify risks over which experts might disagree (Lee & Scheufele 2006; Brossard & Nisbet 2007; Akin et al. 2017). They also tend to perceive them as more beneficial and less risky (Kim et al. 2014).

Deference to scientific authority (Brossard & Nisbet 2007) and related concepts such as cultural authority of science (Shapin 2007; Gauchat 2011) are conceptualized as stable, long-term predispositions cultivated and reinforced by the educational system and exposure to popularized science (e.g. NOVA, science museums, science magazines). Deep-seated belief in the authoritative position of science is similar to, but conceptually distinct from, social and institutional trust, which are less stable than core belief systems. Trust tends to be more variable and issue-specific, and can vary depending on individual views about specific fields and applications of science and different types of scientists (Critchley 2008).

In this study we focus on one particular dimension of authoritative beliefs about science: the tendency to privilege science as a superior source of knowledge, which we refer to as belief in the "authority of scientific knowledge." Given the above considerations, we predict that individuals who more strongly believe in the authority of scientific knowledge will perceive gene editing wildlife as more beneficial, less risky, and more morally acceptable. To test this prediction, we pose the following hypothesis:

H1) Belief in the authority of scientific knowledge will be related to favorable perceptions of benefits, risks, and moral acceptability.

Individuals who embrace the authority of scientific knowledge might also privilege scientific reasoning as a moral paradigm—a moral orientation anchored in the idea that a "universal morality" can be "established on the basis of 'sound scientific argument'" about consequences (Wagner et al. 2001). When scientific reasoning becomes a paradigm for moral reasoning in debates about genetic engineering, for example, arguments tend to focus on the consequential outcomes of the technique, while deflecting intrinsic concerns directed at the technique itself. Genetic engineering is considered neither good nor bad, but value-free (Verhoog 2003; Cooley & Goreham 2004; Nature 2007). In the present study we ask whether the relationship between belief in the authority of scientific knowledge and judgments about the moral acceptability of gene editing wildlife will depend on perceptions about outcomes (i.e. relative benefits and risks). We explore this possibility with the following research question.

RQ4) Will the relationship between belief in the authority of scientific knowledge and moral acceptability be moderated by relative benefit-risk perceptions?

Messing-with-nature beliefs

Beliefs about naturalness can make technologies, technological products, and environmental interventions more or less acceptable to people (Rozin et al. 2004; Gaskell et al. 2010; Corner & Pidgeon 2015). Beliefs about unnaturalness are often linked with unfavorable attitudes toward synthetic biology, GM foods, and genetic engineering more broadly (Shaw 2002; Gaskell et al. 2010; Pauwels 2013). Focus group participants and survey respondents who oppose genetic engineering often explain their rejection based on a belief that it "messes" with nature, or allows humans to "play God" (Wagner et al. 2001; Shaw 2002; Pew Research Center 2018b).

Previous studies report that focus groups refer to messing with nature or playing God to articulate both intrinsic moral concerns reflecting a view of nature as sacred, and concerns about humans' limited capacity to predict and control outcomes (i.e. benefits and risks) when intervening in complex natural systems (Wagner et al. 2001; Corner et al. 2013). Given the above considerations, we predict that messing-with-nature beliefs will be linked with unfavorable views about the benefits, risks, and moral acceptability of gene-editing wildlife. To test our prediction, we pose the following hypothesis.

H2) Messing-with-nature beliefs will be related to unfavorable perceptions of benefits, risks, and moral acceptability.

Attention to science news

The amount and content of media coverage can play an influential role in shaping public perceptions of advances in science and technology (Nisbet et al. 2002). Media coverage of technologies can provide audiences with a mental shortcut in forming attitudes about emerging technologies (Scheufele & Lewenstein 2005). Researchers have identified several patterns in how media cover emerging technologies. Early coverage tends to be largely positive, framing emerging technology in terms of progress and emphasizing benefits while downplaying risks (Nisbet & Lewenstein 2002; Nisbet et al. 2003; Nisbet & Huge 2006). At the same time, anecdotal evidence suggests public discourses on CRISPR may also be permeated by an unusual degree of critical reflexivity, with CRISPR scientists themselves drawing attention to possible risks and ethical dimensions (Baltimore & Berg 2015; Doudna 2015). Given the above considerations, we pose the following research question.

RQ5) Will attention to science news be related to favorable perceptions of benefits, risks, and moral acceptability?

Methods

Data collection

The data used for the analyses reported in this study were obtained in an online survey of 1,600 U.S. adults conducted by YouGov in December 2016 and January 2017. The completion rate was 41.7%. To ensure representativeness across sociodemographic characteristics, YouGov matched respondents drawn from a panel of U.S. residents to a sampling frame on gender, age, race, education, political ideology, party identification, and political interest. The sampling frame was constructed using stratified sampling from the Census Bureau's 2010 American Community Survey. Matched cases were weighted to the sampling frame using propensity scores. YouGov excludes non-U.S. residents by profiling panelists on full mailing addresses and blocking non-U.S. IP addresses. Additionally, incentives for participating in surveys are delivered by postal mail.

Before the survey was distributed, study approval was obtained from the University of Wisconsin Institutional Review Board. Question items used in analysis were part of a survey that also included questions about other gene-editing applications, including human genome editing, which were used for other public opinion research studies. Sample size was determined by the number of variables examined and design of this and other studies drawing on the survey. Questions from the survey used in the present study are described below.

Measures

Risk and *benefit perceptions* were each measured as the averaged response to two items. We asked respondents how risky and how beneficial they thought gene editing plant and animal wildlife will be for 1) nature; and 2) humans (1 = not at all risky; 5 = very risky); and (1 = not at all beneficial; 5 = very beneficial). We also created a relative measure of *benefit-risk perceptions*, by subtracting the risk variable from the benefit variable (-9 = risks outweigh benefits completely; 9 = benefits outweigh risks completely).

Moral acceptability was measured as the averaged response to two items. We asked respondents how much they agreed that it would be morally acceptable to edit genes in wildlife to 1) improve endangered plants' and animals' chances for survival; and 2) decrease or eliminate local populations of animals or plants that are causing environmental problems (e.g. invasive, non-native species) (1 = strongly agree; 7 = strongly disagree).

Wrong purposes was measured with two separate items. We asked respondents how much they agreed that gene editing wildlife could be easily used for the wrong purposes when used to 1) improve endangered plants' and animals' chances for survival; and when used to 2) decrease or eliminate local populations of animals or plants that are causing environmental problems (e.g. invasive, non-native species) (1 = strongly agree; 7 = strongly disagree).

Authority of scientific knowledge was measured as the averaged response to two items. Respondents were asked to indicate how much they agreed that 1) science is the best way that society has for producing reliable knowledge; and 2) science is the best way to understand the world (1 = strongly disagree; 7 = strongly agree).

Messes-with-nature belief was measured as the averaged response to two items. Respondents were asked to indicate how much they agreed editing genes in wildlife 1) messes with nature; and 2) allows humans to play God (1 = strongly disagree; 7 = strongly agree). A Pearson's correlation coefficient for these two items showed good reliability (r = .75). However, to further evaluate whether it would be appropriate to treat these two items as a single measure in the current study, we also examined whether they exhibited similar patterns of correlation with our outcome variables. We found very similar correlations for "playing God" and "messing-with-nature" in relation to benefits (r = -.38; r = -.40), risks (r = .51; r = .53), and moral acceptability (r = -.33; r = -.31).

Attention to science news was measured by averaging responses to three items asking people how much attention they give to news stories about 1) science and technology; 2) new scientific tools or developments, such as CRISPR-Cas9; and 3) political or ethical implications of emerging technologies, such as gene editing (1 = none; 5 = a lot).

Ideology was measured by averaging responses to two items asking respondents whether they considered themselves "liberal" or "conservative" with respect to 1) economic issues; and 2) social issues (1 = very liberal; 7 = very conservative). *Religiosity* was measured by asking respondents "how much guidance does religion provide in your everyday life?" (0 = no guidance at all; 10 = a great deal of guidance).

Finally, we included demographic factors to control for the effect of age, gender, and education. *Age* was measured as a continuous variable (M = 50, SD = 16.55). *Gender* and *education* were measured as dichotomous variables (42% male) and (0 = no college; 1 = at least some college) (62% at least some college). Variable means, standard deviations, and bivariate correlations are presented in Table 1.

- Table 1 here –

Data analysis

All analyses were conducted with R (Version 3.0.3; http://www.r-project.org/). We analyzed the data using three paired-sample t-tests to explore our first three research questions and four hierarchical ordinary least squares (OLS) regression models to test our two hypotheses and final two research questions. For each regression model we calculated partial eta-squared (η_p^2) to quantify predictor variable effect sizes. Effect sizes using η_p^2 are considered small at .01, medium at .09, and large at .25 (Tabachnick & Fidell 2007; Watson 2017). All categorical predictors were centered using contrast coding. Visual inspection of residual plots did not reveal any obvious deviations from assumptions of linearity or homoscedasticity. Tests for multicollinearity indicated that the variance inflation factors (VIF) for all predictor variables in regression models fell well below the common threshold value (O'brien 2007).

Results

We begin with a brief descriptive overview of responses to questions used to measure participant views of gene editing wildlife. First Figures 1 and 2 illustrate responses to items measuring our regression outcome variables—perceptions of benefits, risks, and moral acceptability. As Figure 1 illustrates, 84.4—87.2% of Americans thought gene editing wildlife would be at least somewhat risky for nature and humans, but were relatively split about whether it would be beneficial. Figure 2 shows that a relative majority agreed applications to improve survival in endangered species would be morally acceptable, while a relative majority thought applications to decrease or eliminate local populations of environmentally problematic wildlife would not be morally acceptable. Additionally, a majority of respondents agreed that gene editing wildlife messes with nature (70.8%) and allows humans to play God (59.4%) (also reported in: AUTHORS REMOVED). And large percentages agreed that gene editing was likely to be used for the wrong purposes (72—75%).

- Figures 1 & 2 here –

Our statistical analyses begin with three paired sample t-tests exploring Research Questions 1, 2, and 3. Our first test shows respondents perceived the risks of gene editing wildlife as outweighing the benefits (mean difference = -.96; $t(1,525) = 25.79$; $p < .001$). The second test shows respondents viewed applications to improve survival in endangered wildlife as more morally acceptable than applications to reduce or eliminate wildlife populations (mean difference = -.24, $t(1,555) = 6.13$; $p < .001$). Finally, the third test shows respondents more strongly agreed that applications to decrease or eliminate environmentally problematic wildlife populations could be used for the wrong purposes (mean difference = .13, $t(1,557) = 4.65$; $p < .001$), compared with applications to improve survival in endangered species.

Analyses testing our two hypotheses are presented in Table 2. As proposed in Hypothesis 1, authority of scientific knowledge was positively related to benefits and moral acceptability, and negatively related to risks. Results also show authority of scientific knowledge most strongly related to benefits (η_p^2 = .11) and moral acceptability (η_p^2 = .09). Results also supported Hypothesis 2; messes-with-nature beliefs were negatively related to benefits and moral acceptability, and positively related to risks. Results also show messing-with-nature most strongly related to risks (η_p^2 = .27).

- Table 2 here –

To test Research Question 4, we added benefit-risk perceptions and an interaction term (benefit-risk perceptions x authority of scientific knowledge) to the regression predicting moral acceptability (Model 4, Table 2). Results show moral acceptability judgements were more strongly related to benefit-risk perceptions among individuals who more strongly believe in the authority of scientific knowledge (Fig. 3). Finally, in testing Research Question 5, we found that attention to science news was negatively related to risks and positively related to benefits. Models 1, 2, 3 and 4 accounted for 21.7—33.9% of the variance in the dependent variables.

- Figure 3 here –

Discussion

This study provides a systematic assessment of public attitudes about gene editing wildlife as a tool for conservation. It also sheds light on how these attitudes are related to cultural dispositions toward science, messing-with-nature beliefs, and attention to science news. Our results suggest that Americans are generally skeptical about the outcomes of gene editing wildlife. On average, respondents thought that risks would outweigh benefits, and large majorities thought gene editing wildlife would be at least somewhat risky for humans (84%)

and nature (87%). These percentages appear to be high when compared, for example, to public risk perception measures involving GM food. A Pew Research Center survey found that 59% of Americans think it is at least "fairly likely" that GM foods will lead to health problems for the population as a whole and 56% think it is at least "fairly likely" that GM foods will create problems for the environment (2018a).

In this study, there also appeared to be considerable concern about accountability, with more than 70% agreeing that gene editing wildlife could easily be used for the wrong purposes. While the difference was small, this concern was significantly greater for gene editing used to decrease or eliminate environmentally problematic wildlife populations than for applications to improve survival in endangered species. There were no clear majorities of opinion in response to questions about the moral acceptability of gene editing wildlife. On average, however, moral acceptability evaluations were significantly greater for applications to improve survival in endangered species compared with applications to decrease or eliminate environmentally problematic wildlife populations.

These results suggest moral frames could influence how the American public responds to proposals to gene edit wildlife for conservation. Advocates and opponents have already begun to leverage moral framing to advance their viewpoints. Some advocates, for example, refer to gene editing wildlife applications as "genetic rescue" (Revive & Restore 2016). Meanwhile, others have come out against gene editing as a conservation tool, warning against the release of "genocidal genes" or "genetic extinction technology" (Civil Society Working Group on Gene Drives 2016; Friends of the Earth 2016).

Several limitations should be considered in interpreting our results. First, our study does not account for the possibility that respondent's attitudes toward related but more familiar genetic engineering applications, such as GMOs and GM food, may spill over into evaluations of

the less familiar issue of gene editing wildlife (Akin et al. 2018). Future research in this area should take into account whether, or to what degree, attitudes about gene editing wildlife are linked to attitudes toward other more familiar genetic engineering applications.

Furthermore, we asked respondents to evaluate gene editing wildlife without providing examples of specific applications. A survey presenting respondents with a range of possible conservation applications targeting different organisms might yield somewhat different results. Previous studies have revealed greater acceptance for genetic engineering applications involving plants and micro-organisms compared to those involving animals (Frewer et al. 1997; Dragojlovic & Einsiedel 2013). Furthermore, individuals may view invasive species control using gene editing to subvert reproduction as more humane when presented with existing alternatives using traps, guns, and poison (e.g. Borel 2017). Attitudes toward wildlife gene editing may also vary depending on the purpose of the application. Future research should compare attitudes toward applications representing a wider range of anthropocentric and conservation goals. This might include, for example, applications to prevent the spread malaria by mosquitos, protect crops from pests, and to create extinct species proxies (i.e. de-extinction) (Esvelt et al. 2014; NASEM, 2016; Novak et al. 2018).

Prior research shows that perceptions of the risks, benefits, and moral acceptability of genetic engineering technologies varies among countries. For example, in a meta-analysis of research on public perceptions of GM foods, risk perceptions were found to be greater in Europe than North America and Asia. The reverse was true of benefit perceptions, while moral concerns were higher in North America and Asia (Frewer et al. 2013). It is unclear how public perceptions of gene editing wildlife for conservation will vary across international boundaries. There have been few efforts in North America or beyond to systematically assess public perceptions of gene editing wildlife for conservation purposes. One exception includes a survey

in New Zealand, in which 32% of the 8,000 people surveyed were comfortable with pest control technologies like gene drives, while 18% felt they should never be used and 50% were undecided or wanted strong controls (Biological-Heritage National Science Challenge 2017).

While our study involved only U.S. adults, our findings can help inform the collection of data in other countries. Consulting and engaging with the public about emerging issues is tricky when public awareness is low. Early opinions, including those uncovered in this study, are likely to be provisional. Thus, consulting the public should be an iterative process in which societies continually revisit issues, allowing people to reframe their views in the light of subsequent experience (Jasanoff et al. 2015). While issue-specific perceptions are often subject to change, systems of deeply held beliefs are more resistant.

Relevant to this, our second set of analyses highlight the important role of beliefs about science in predicting views about gene editing wildlife. Individuals who more strongly believed in the authority of scientific knowledge held more favorable views of gene editing wildlife, and particularly views regarding the benefits and moral acceptability. Consequently, such individuals may be especially receptive to claims about benefits and moral arguments in favor of gene editing wildlife. Belief in the authority of scientific knowledge also appeared to play a role in the relationship between relative benefit-risk perceptions and moral acceptability judgments. We found that perceptions about the relative benefits and risks of gene editing wildlife more strongly predicted moral acceptability judgments among individuals with greater belief in the authority of scientific knowledge. These results should be interpreted with caution. Because this study relies on correlational data, we cannot be sure about the causal direction of the relationship. It's possible that instinctive moral judgements about gene editing wildlife drive benefit-risk perceptions, rather than the other way around (Haidt 2001).

We also tested the relationship between attention to science news and views of gene editing wildlife. While previous research shows that early media coverage of emerging technologies tends to emphasize benefits while downplaying risks (Nisbet & Lewenstein 2002; Nisbet et al. 2003; Nisbet & Huge 2006), anecdotal evidence suggests public discourses about CRISPR have been permeated by an unusual degree of critical self-reflexivity (Baltimore & Berg 2015; Doudna 2015). Nonetheless, our results revealed a positive relationship between attention to science news and favorable attitudes toward gene editing wildlife. Individuals who paid more attention to science news perceived gene editing wildlife as more beneficial and less risky.

Finally, our findings suggest that concerns about messing with nature are likely to become central to debates about gene editing wildlife. A majority of Americans agreed that gene editing wildlife messes with nature (70.8%) or, relatedly, allows humans to play God (59.4%). This is consistent with previous research indicating that concerns about interfering with nature or disrupting the natural order often loom large in public opinion about agricultural genetic engineering (Wagner et al. 2001; Shaw 2002; Gaskell et al. 2010). Messing-with-nature beliefs were associated with greater moral concern and skepticism about benefits, but most strongly predicted concern about risks. The relationship between messing-with-nature beliefs and risk perceptions was twice as strong as the relationship between messing-with-nature beliefs and perceived benefits or moral acceptability.

Some limitations should be considered when interpreting these results. As noted above, we measured messing-with-nature beliefs by combining two items asking respondents whether they agreed that gene editing “messes with nature” and allows

humans to "play God." We report strong reliability between these items and close correspondence in the way the items correlate with outcome variables. However, we cannot be certain that they necessarily express the same sets of values. We acknowledge this limitation and recommend future research undertake more in-depth exploration of the nature of the relationship between these two terms.

With this limitation in mind, our results highlight the need for renewed focus on what nature means to various publics and expert stakeholders, and what kind of nature we think conservation ought to save and how. The question of how we understand our relationship with nature is gaining importance as advanced gene-editing tools and other modern technologies extend our ability to deliberately shape evolutionary processes and synthesize nature. Debates about gene editing wildlife for conservation are beginning to emerge among stakeholder groups and some conservationists, and have only just begun to enter mainstream dialogue. There is growing need for open debates that engage diverse expert and lay voices. Our results shed light on how people might respond to gene editing wildlife proposals and how those proposals might intersect with different belief systems. We hope the results of this study will help to lay the groundwork for conservation biologists and other scientist stakeholders to organize constructive deliberations with the public about when or whether gene editing wildlife should play a role in future conservation practices.

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Table 1: Factor correlations values with reliability measures for multi-item measures on the diagonal.[a]

Variable	*M*	*SD*	1	2	3	4	5	6	7	8
1. Ideology	4.11	1.68	**.79**							
2. Religiosity	5.80	3.68	.46**	**NA**						
3. Authority of scientific knowledge	4.67	1.49	-.38**	-.26**	**.73**					
4. Messing-with-nature	5.04	1.59	.19**	.22**	-.26**	**.73**				
5. Science news attention	2.69	0.92	-.12**	-.10**	.10**	-.10**	**.84**			
6. Risk	3.57	1.00	.18**	.23**	-.29**	.55**	-.11**	**.73**		
7. Benefit	2.63	1.00	-.26**	-.21**	.48**	-.42**	.20**	-.51**	**.72**	
8. Moral acceptability	3.86	1.47	-.25**	-.23**	.39**	-.40**	.17**	-.45**	.58**	**.57**

Note. * $p < .05$; ** $p < .01$. *M* and *SD* are used to represent mean and standard deviation, respectively. Perceptions of risk and benefit, and science news attention were measured on a unipolar 5-point scale, and religiosity on a 10-point scale. All other variables measured on a bipolar 7-point scale. [a] Cronbach's alpha is reported for multi-item measures with more than two items, and Pearson's r is used as a measure or reliability for two-item measures.

Table 2. Results for analyses regressing the predictor variables on perceptions of benefits, risks, and moral acceptability

	Benefits			*Risks*			*Moral acceptability*					
		Model 1			Model 2			Model 3			Model 4	
Variable	SE	β	η_p^2	SE	β	η_p^2	SE	β	η_p^2	SE	β	η_p^2
Gender	.04	-.05	–	.04	-.01	–	.07	.01	–	.07	.04	–
Age	.02	.09**	.01	.02	.08**	.01	.03	-.05	–	.03	-.05	–
Education	.05	-.07	–	.05	.06	–	.07	.06	–	.07	.12	–
Ideology	.03	-.09**	.01	.03	.05	–	.04	-.08	–	.04	-.02	–
Religion	.02	.03	–	.02	.05**	–	.04	.04	–	.04	-.05	–
Authority of scientific knowledge	.02	.35**	.11	.02	-.14**	.02	.04	.47**	.09	.04	.33**	.05
Messing-with-nature beliefs	.02	-.34**	.14	.02	.52**	.27	.04	-.43**	.10	.04	-.12**	.01
Science news attention	.02	.07**	.01	.02	-.05*	–	.04	.01	–	.04	-.06	–
Adjusted R^2 (%)		32.5**			34.5**			21.7**				
Benefit-risk perceptions										.04	.64**	.17
Interactions												
Authority of scientific knowledge x benefit-risk perceptions										.03	.10**	.01
Adjusted R^2 (%)											33.9**	

Note. * indicates $p < .05$; ** indicates $p < .01$; β represents standardized regression weights; η_p^2 represents the partial-eta correlation squared. Only partial-eta correlations of at least .01 are displayed. Perceptions of risk and benefit were measured on a unipolar 5-point scale, while moral acceptability was measured on a bipolar 7-point scale.

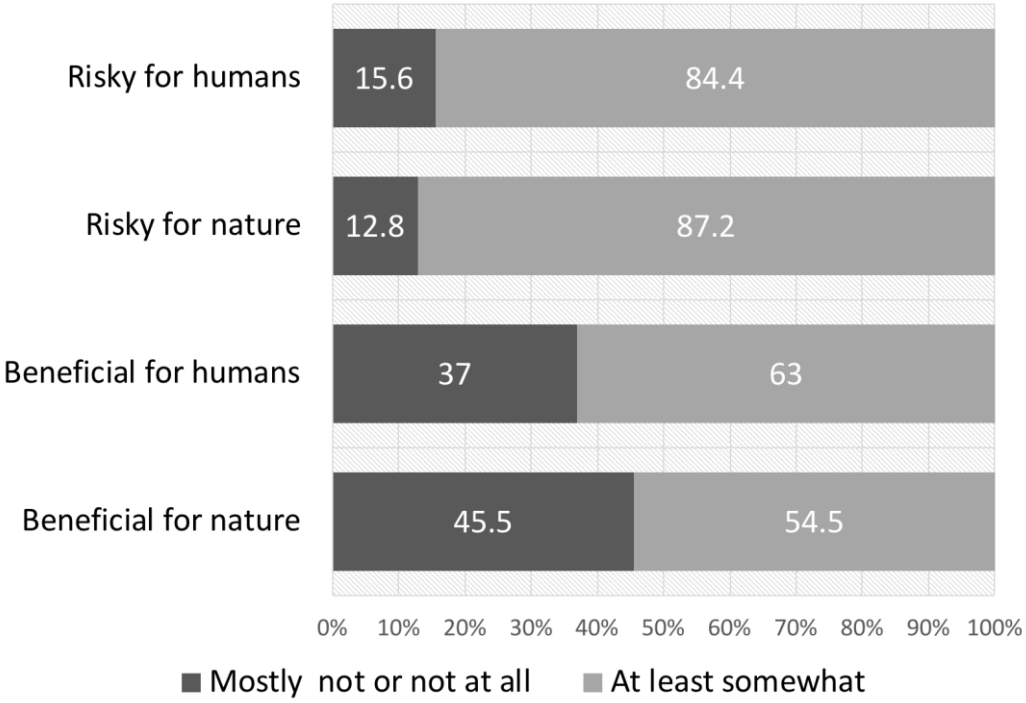

Figure 1. Percent of respondents who thought gene editing wildlife would be somewhat risky/beneficial or who thought it would be mostly not or not at all risky/beneficial.

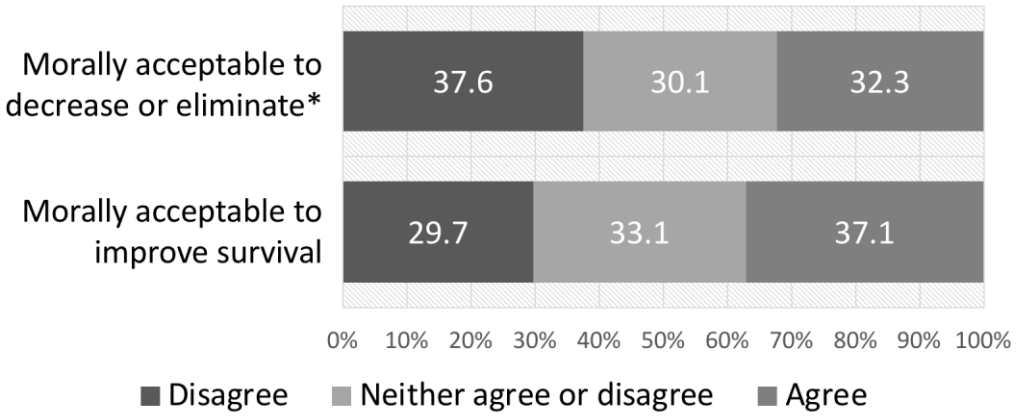

Figure 2. Percent respondent agreement with statements about the moral acceptability of gene editing wildlife for applications to decrease or eliminate wildlife populations versus applications to improve survival in endangered wildlife. *Note*: frequencies for the decrease or eliminate applications item previously published in a research report (see, AUTHORS REMOVED).

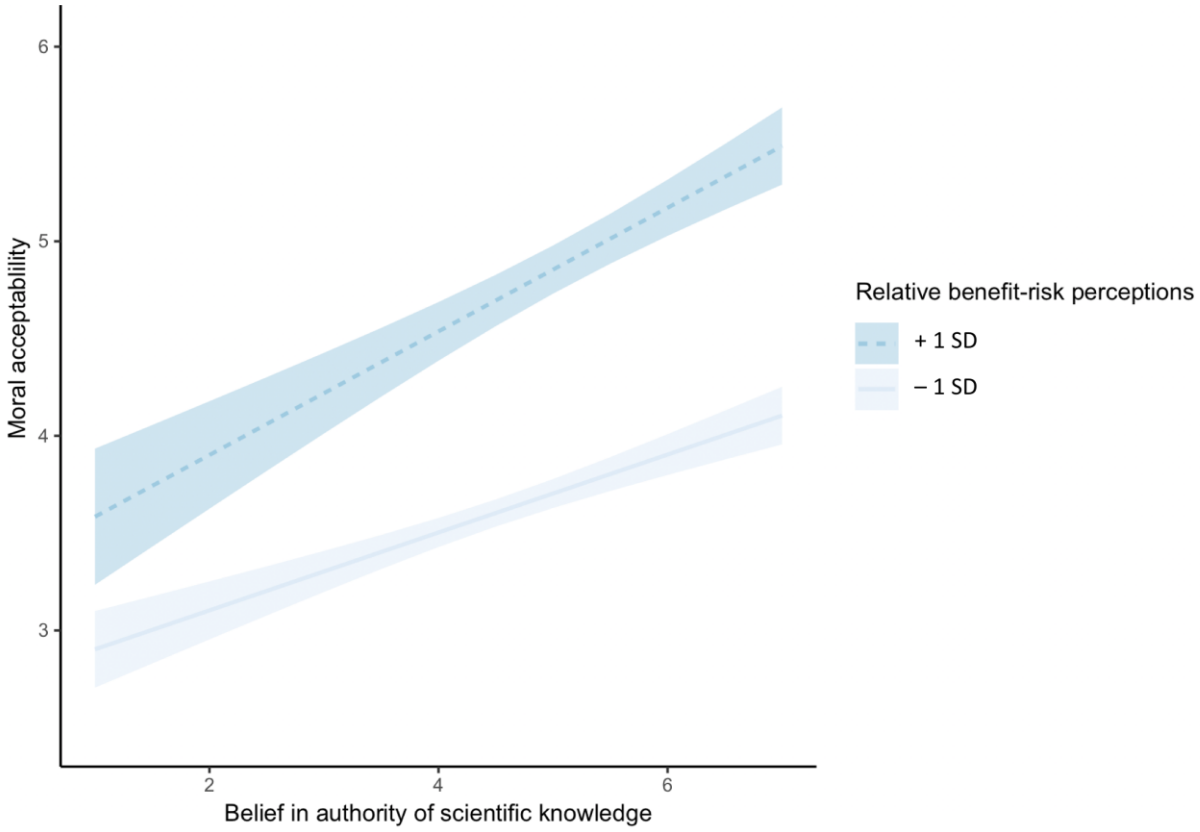

Figure 3. Relationship between perceived moral acceptability of gene editing wildlife and belief in the authority of scientific knowledge as moderated by relative benefit-risk perceptions. *Note:* Y-axis scores based on 1-7 scale