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Animal Rights and the Problem of r-Strategists

Kyle Johannsen [1]

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Abstract Wild animal reproduction poses an important moral problem for animal rights theorists. Many wild animals give birth to large numbers of uncared-for offspring, and thus child mortality rates are far higher in nature than they are among human beings. In light of this reproductive strategy – traditionally referred to as the 'r-strategy' – does concern for the interests of wild animals require us to intervene in nature? In this paper, I argue that animal rights theorists should embrace fallibility-constrained interventionism: the view that intervention in nature is desirable but should be constrained by our ignorance of the inner workings of ecosystems. Though authors sometimes assume that large-scale intervention requires turning nature into an enormous zoo, I suggest an alternative. With sufficient research, a new form of gene editing called CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) promises to one day give us the capacity to intervene without perpetually interfering with wild animals' liberties.

Keywords Animal rights · R-strategists · Wild animals · CRISPR

1 Introduction

Animal rights (AR) theory has traditionally focused on the negative duties that follow from ascribing moral status to sentient animals, e.g., obligations not to kill them, imprison them, etc. (Singer 1975; Regan 1983).[1] However, ascribing moral status to animals also entails that we owe positive duties to them. After all, we owe duties of 'humanity' or assistance to human beings in need, even when we have no special

[1]It should be noted that I use the term "animal rights theory" fairly broadly in this paper. My use of it includes, for example, the utilitarian view that animals (and humans) have moral status but not inviolable rights. In fact, my own view is that animals have rights, but not *inviolable* rights, as both their rights and the rights of humans may sometimes be overridden for the sake of beneficence.

✉ Kyle Johannsen
9kj29@queensu.ca

1 The Department of Philosophy, Saint Mary's University, 923 Robie St., Halifax, NS B3H 3C3, Canada

relationship with them. If, as AR theorists believe, animals are our moral equals, then don't we owe similar duties to them, too?[2] With respect to wild animals in particular (as opposed to domesticated or liminal animals),[3] the extension of positive duties presents a difficulty. The wild is an incredibly violent place. It is normal for animals to lethally attack one another, often in order to consume their flesh. Does AR theory, when consistently applied; require us to intervene in the predatory-prey relationship (Callicott 1980, 320; Cohen and Regan 2001, 30)? Does it require turning nature into a massive zoo, i.e., a place where wolves are fenced off from deer, tigers are fed soy protein and given tethered balls to bat at, and breeding is tightly regulated?

Though AR theorists can arguably handle the problem of predation without conceding that their position commits them to large-scale interventions in the wild, predation isn't the only problem we face. A distinct and largely neglected problem is raised by wild animal reproduction. Many animals ensure the survival of their species not by caring for their young, but by producing large numbers of them. Biologists have dubbed this particular reproductive strategy the 'r-strategy' (MacArthur and Wilson 1967; Pianka 1970; Jeschke et al. 2008). As a result of this strategy, child mortality rates in many animal species are far higher than anything we see in the human case.

In this paper, I argue that AR theorists should adopt a qualified commitment to intervening in the wild via a new form of genetic intervention called CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats).[4] More specifically: in section 3 I canvass various responses to the 'problem of predation', and in section 4 I distinguish a second problem - the 'problem of r-strategists' – and argue that it poses a more significant challenge to AR theorists who are against intervention. In the face of this problem, the most plausible response from an AR perspective is to embrace fallibility-constrained intervention, i.e., to accept the view that intervention is desirable but should be constrained by our ignorance of the inner workings of ecosystems (Cowen 2003; McMahan 2010; Sözmen 2013; Horta 2013, 2015; Tomasik 2015). Though authors sometimes assume that the goal of large-scale intervention must be to turn nature into an enormous zoo (Nussbaum 2007, 379; Donaldson and Kymlicka 2011, 164; Donaldson and Kymlicka 2013, 154–157), I argue in section 5 that CRISPR promises to one day give us the capacity to assist wild animals on a large scale without perpetually interfering with their liberties.

[2] It is important to note that we owe certain duties of assistance even to distant strangers. According to Clare Palmer, we owe positive obligations to domesticated but not wild animals because we have no special relationship with the latter (Palmer 2010, chapter 5; Palmer 2015). Her argument fails because it assumes that duties of assistance are entirely contingent upon special relationships (Donaldson and Kymlicka 2011, 162; Faria 2015).

[3] The difference between wild and domesticated animals is a familiar one, but 'liminal animals' is a relatively new category in the AR literature. Liminal animals are undomesticated animals that, unlike wild animals, live in and around human communities in order to take advantage of the opportunities they present for food and shelter. Examples include squirrels, pigeons, raccoons, etc. (Donaldson and Kymlicka 2011, 62–69).

[4] Technically speaking, CRISPR just refers to a structural feature present in the genomes of different bacteria. The actual gene editing is done by an associated enzyme called Cas9 in combination with a guide RNA molecule that targets the desired part of the genome to be modified. Nevertheless, the acronym 'CRISPR' is now typically used to refer to this new form of gene editing (Doudna and Charpentier 2014, 1 and 3). For an informative and accessible article about CRISPR, see Ledford 2015b.

2 Methodological Preliminary

Before I begin, it's worth noting that in a couple of places throughout the paper I draw on intuitions about what we owe to humans in order to draw conclusions about what, from an AR perspective, we owe to r-strategist animals. On the assumption that humans and animals are moral equals, it seems to follow that if I owe a particular duty to another human being in a particular set of circumstances, then I also owe an analogous duty to an animal in relevantly similar circumstances (on a suitably broad understanding of 'circumstances').[5] For example, parents owe certain special obligations to their children. When someone brings a vulnerable, dependent human infant into the word, they in turn incur an obligation to protect and care for her. By analogy, then, it could be argued that we, as a group, owe similar duties to vulnerable, dependent animals that we've brought into the world, i.e., to domesticated animals (Palmer 2010, 91–95). The strength of analogical arguments like this always depend on the extent to which the circumstances of the alleged analogue are sufficiently similar, and thus such arguments are weak when there is too much relevant dissimilarity.[6] This *form* of argument is inductively strong, however, if we assume that animals are our moral equals.

Since my paper is concerned with duties to r-strategists, the human case I'll discuss is meant to be roughly analogous. The difficulty is that there are no human groups in circumstances roughly analogous to those of r-strategists, i.e., no human groups with similar birth rates, life histories, etc. As a result, applying the above-described analogical method to the case of r-strategists required constructing a hypothetical scenario (see my discussion near the end of section 4 and the end of section 5). Strange as my scenario may be, though, I ask that the reader be patient. Moral philosophy sometimes takes us in peculiar directions, and we shouldn't allow an aversion to peculiarity prevent us from thinking through an important moral issue.

3 Animal Rights Theory and the Problem of Predation

Most people who care about the interests of animals have the intuition that, with respect to wild animals, our obligation is specifically to leave them alone. In other words, they think that we should refrain from harming them, but that we should also refrain from paternalistically interfering with them. Given this 'laissez-faire' intuition (Palmer 2010), it is not surprising that,

[5] Relevant circumstances might include such diverse things as, for example, whether or not the duty bearer has a personal history with the being to whom the duty is owed, the availability of financial resources, the physical abilities of the parties, etc. For examples of the kind of analogical reasoning I describe, see my references to Cowen 2003 and Simmons 2009 in footnote 7. See also Palmer 2010 and Donaldson and Kymlicka 2011. Much of what Palmer, and Donaldson and Kymlicka, conclude about our obligations to animals in different relational contexts is argued for on the basis of human analogues.

[6] There are some relevant disanalogies between parental duties and our duties to domesticated animals. The relationship between parent and child is a personal one, and the relevant duty is owed by one individual to another. Though the relationship between a breeder and the animals she breeds is closely analogous, our relationship with the class of domesticated animals is impersonal, and the relevant duties are collective. Palmer is aware of the difficulties with her analogy, however. For her thoughts on the matter and on related issues, see Palmer 2010, 95 and chapter 6. For an alternative analogy between domesticated animals and human slaves, see Donaldson and Kymlicka 2011, 74 and 79–80.

when confronted with the question of what to do about predators, many AR theorists attempt to escape the conclusion that their position commits them to intervening.[7]

One widely accepted, rather plausible argument against intervening in the predator-prey relationship invokes our epistemic limitations. According to this argument, attempting to systematically intervene would be futile at best and ecologically disastrous at worst. After all, the workings of ecosystems are extremely complex. It's not implausible to think that any really serious attempt to turn nature into an enormous zoo would cause more harm than good (Singer 1975, 238–239; Simmons 2009; Ladwig 2015, 297–299). Though this argument provides a consistent basis for AR theorists to reject large-scale interventions, there's also a catch. If the reason we should reject large-scale intervention is specifically the unacceptable risks associated with it, then AR theorists ought to be willing to endorse the following hypothetical claim: "If we could intervene in the predator-prey relationship without risking ecological disaster, then we should." What's more, if AR theorists accept the above hypothetical, then they should also advocate taking whatever steps are needed to make safe intervention a real option in the future, e.g., ecological research, pilot projects that test the effects of different types of intervention, etc. In fact, a number of writers in the literature have come to accept that large-scale intervention is desirable but that we should recognize our fallibility as a constraint (see the authors cited on page 2).[8]

Perhaps the most plausible argument in the AR theory literature that does not lead to fallibility-constrained intervention is what might be called the 'flourishing argument.' According to this argument, even if we could intervene in the predator-prey relationship without risking ecological disaster, doing so would jeopardize wild animals' capacity to flourish. Originally put forward by Jennifer Everett (Everett 2001, 54–55), the most recent and plausible version of the flourishing argument can be found in Sue Donaldson's and Will Kymlicka's book *Zoopolis*. According to Donaldson and Kymlicka, the kind of flourishing at stake is specifically wild animals' *collective* flourishing. Though it is false to say that *individual* victims of predation flourish, preventing predation would require a tremendous amount of interference in the collective ways of life that wild animals partake in, e.g., restricting freedom of movement in order to separate predators from prey, infringing upon reproductive freedom in order to control the breeding of prey species, etc. As terrible as

[7] I discuss a couple of such escape efforts in this section, one of which invokes our epistemic limitations, the other of which claims that even ecologically safe intervention, were it feasible, is contrary to wild animals' flourishing. According to a third response, we aren't required to rescue prey because predators are not agents and are thus not responsible for their own actions (Regan 1983, 357). I think this response fails because even if we accept the controversial claim that animals are *merely* patients, a threat's lack of agency does not mean that the one who is threatened has no claim to assistance. For example, we're presumably required to save a person who's threatened by a boulder or a tornado in the event that we could do so without endangering ourselves (Cowen 2003, 176; Simmons 2009, 19–20). For a discussion of animals' varying capacity for agency, see Donaldson and Kymlicka 2011, 65–66, 108–122, and 175–177.

[8] Fallibility-constrained interventionism is best understood as a claim about the desirability of ecologically safe intervention in the wild, and desirability claims are different from action-guiding claims (Cohen 2008, 250–254; Cohen 2009, 46–52; Gilabert 2011, 56 and 59–63). Though plausible action-guiding claims must also be feasible, desirability claims are hypothetical: they're claims about what we should do in the event that it were feasible. As such, a desirability claim remains true even when the relevant action is infeasible: the claim "If action X was feasible, then person Y should perform it" is true even if person Y cannot feasibly perform action X. Since it is specifically a desirability claim, the plausibility of fallibility-constrained interventionism is therefore unaffected by the fact that, to a large extent, it is presently infeasible to intervene in nature without risking ecological disaster. Fallibility-constrained interventionism merely states that (a) we should intervene if we could safely do so, and (b) that the truth of (a) implies that we have reason to bring about a state of affairs from which safe intervention is feasible.

predation is, a risk-free life of perpetual, sheltered dependency is not a flourishing one for wild animals. Flourishing requires facing certain risks, and for the members of prey species, predation is one of them (Donaldson and Kymlicka 2011, 179–187).

In the next section, I discuss a problem related to but different from the problem of predation. We can call this problem 'the problem of r-strategists'. With the exception of Oscar Horta's work (Horta 2010, 2013, 2015), questions about r-strategists have been largely ignored in the AR literature.[9] This is unfortunate. Though the flourishing argument arguably succeeds at handling the problem of predation, r-strategist animals pose a more difficult challenge.

4 The Problem of r-Strategists

Broadly speaking, there are two evolutionary reproductive strategies species employ: the K-strategy and the r-strategy (MacArthur and Wilson 1967; Pianka 1970).[10] The K-strategy is used by many mammals, and it ensures species survival by restricting reproduction to a small number of offspring who are intensively cared for. Examples of K-strategists include large mammals such as deer, bears, elephants, etc. The r-strategy, by contrast, is used by many lizards, amphibians, fish, and small mammals, and it ensures species survival through quantity. Instead of restricting reproduction and providing intensive care, r-strategists produce large numbers of uncared-for offspring, the majority of whom die painful deaths shortly after hatching or birth.

The r-strategy poses a serious issue for AR theorists reluctant to embrace fallibility-constrained intervention. The reason is that the amount of suffering and premature death associated with the r-strategy is enormous. For example, consider the results of a population study concerning *Podarcis muralis*: the common wall lizard (Vitt and Caldwell 2009, 139; Barbault and Mou 1988). The population in the study (which was located in a cemetery in France) started at a total of 570 members (570 eggs). Of those 570, 194 lived to 1 year of age, 48 reached their second year of life, 25 made it to year 3, and only 12 reached year 4. Some of the eggs did not hatch at all, so a portion of the 'mortality' represented by the drop from 570 to 194 did not involve the death of sentient beings. Still, even if we (implausibly) assume that the initial drop in population size is entirely attributable to unhatched eggs; most of these wall lizards experienced an abysmal fate. Only 48 of 194 lizards reached the age of sexual maturity (year 2): that's roughly 25% of the population.[11] Considering that a healthy, well-nourished wall lizard can live for up to 10 years, premature death was apparently the norm for this population (Burton et al. 2002, 2850).

The wall lizards in the above study are not idiosyncratic. Many amphibians and lizards have similar life histories. High early-life mortality rates are normal for crocodilians, turtles, and

[9] Additional exceptions were published in Faria and Paez 2015. See, for example, Cunha 2015 and Tomasik 2015.

[10] It should be noted that my use of the terms 'K-strategist' and 'r-strategist' does not mean I endorse the theory with which they are associated. The predictions that theory makes about evolved traits have often proven false, but the classificatory terminology it employs is still helpful and in common use. It should also be noted that though using the terms 'K-strategist' and 'r-strategist' in a classificatory manner suggests a dichotomy, it's more accurate to think of them as opposite points on a spectrum: some animals are clearly K-strategists, some are clearly r-strategists, but many also lie somewhere in between. Many thanks to Oscar Horta and to an anonymous reviewer for drawing my attention to the importance of qualifying my use of these terms. For a helpful secondary source concerning the r and K-strategies, see Jeschke et al. 2008.

[11] For physical information about the wall lizards in their study, see Barbault and Mou 1988, 41.

amphibians that develop indirectly (have a larval stage in their life history). In fact, species in these groups typically experience an early-life death rate of greater than 90% (Vitt and Caldwell 2009, 138–139).

It is among fish species in particular that we find some of the most extreme examples of the r-strategy. Consider a particular example discussed by Oscar Horta: the Atlantic Cod population located on the Gulf of Maine's bank (Horta 2010). An adult female cod lays anywhere from many thousands to many millions of eggs each time (Jørstad et al. 2007, 11). Furthermore, it was estimated that in 2007 the Gulf of Maine's bank contained 33, 877 metric tons of 'spawning stock', i.e., one million cod old enough to breed if we assume an average weight of 33.877 kg per cod (Mayo et al. 2009, 100). Even if only a small proportion of their eggs hatch, it remains true that a tremendous amount of suffering and premature death occurs every time a more or less stable cod population of this size reproduces. Horta estimates an aggregate total of 200 billion seconds or roughly 6300 years of suffering across the doomed codlings produced per cycle, but the precise figures don't really matter. Whatever the correct amount of suffering and premature death is, it's astronomically high, and this is just for a specific r-strategist fish species in a very specific geographic area.

The problem posed by r-strategists is not entirely separable from the problem posed by predation. After all, predation is one of the causes of death for r-strategists' young. Still, there are a number of important respects in which these problems differ from each other, particularly when we have predation between K-strategists in mind.

First, as terrible as predation is, it is nonetheless compatible with K-strategists' collective flourishing. Some members of prey species must, of course, fall victim to predation, but this is acceptable so long as the amount of suffering and premature death does not exceed a certain threshold. So long as a significant proportion of their young manage to live successful lives, it is appropriate to conclude that K-strategist groups are competently managing the risks they face. By contrast, the members of r-strategist species cannot plausibly be said to collectively flourish (Horta 2013, 115–116; 2015, 22–24). Though a small proportion manage to lead successful lives, AR theorists cannot restrict their concern to successful r-strategists. Any sentient being is morally significant from an AR perspective, and thus all sentient individuals born into r-strategist species must be taken into account when determining whether r-strategists are flourishing. And the facts about r-strategists' life histories suggest that they aren't. As we've already noted, most r-strategists die very painful deaths, e.g., starvation, exposure, and being eaten by predators. Furthermore, most of them die minutes, days, or weeks after birth, and thus do not have the opportunity to experience the enjoyment associated with reaching a stage in life where one has learned to competently manage and be comfortable in one's environment. In combination, these facts suggest that, at best, most r-strategists fail to live flourishing lives. At worst, they suggest that most r-strategists experience more suffering than enjoyment in their lives: that they do not even have lives worth living. Furthermore, since one of the defining characteristics of r-strategist species is that they produce far greater numbers of offspring than K-strategist species, it seems that we're left with an even more depressing conclusion: at best, most wild animals born into the world fail to flourish, and at worst, most do not have lives worth living.[12]

[12] For papers arguing that most wild animals experience more suffering in their lives than enjoyment, see, for example, Horta 2010, 2013, 2015; and Tomasik 2015. For a prominent paper that suggests this conclusion on primarily theoretical grounds, see Ng 1995, especially 269–72 and appendix A. I owe thanks to Sue Donaldson and Howard Nye for comments that drew my attention to the importance of emphasizing the combined significance of the pain and prematurity associated with r-strategists' deaths. In combination, pain and prematurity suggest that most r-strategists either fail to live flourishing lives or do not have lives worth living.

Second, the sheer scale of the problem r-strategists pose is relevant to our assessment of the harms associated with large-scale interventions. The issue of fallibility notwithstanding, much of what's unappealing about turning nature into a zoo, at least from an AR perspective, is the extent to which doing so would interfere with the lives of wild animals. For one, the implementation process would require displacing many animals. How else would predators be separated from prey? What's more, the restrictions on reproduction and freedom of movement that are part and parcel of the zoo scenario are also unappealing. As weighty as our negative obligations are, however, only the strictest of deontologists insist that negative duties *always* outweigh positive duties. Moral common sense dictates that that it is sometimes appropriate to violate a negative duty for the sake of beneficence. For example, it is one of our considered judgments that breaking a trivial promise to a friend in order to assist someone in an emergency is justified (Ross 1930, 88–89). Because it simply describes what most of us already think, the claim that it is sometimes appropriate to drop the priority of negative duties has a different status than the opposing claim that negative duties always take priority. While the latter is an implication of deontological theories such as Immanuel Kant's, the former is pre-theoretical.[13]

The view that the priority of negative duties is not absolute – sometimes referred to as 'moderate deontology' – is applicable not only to minor negative obligations like the duty to refrain from breaking promises, but also to more serious obligations like the duty not to kill or physically harm an innocent person (Nagel 1991, 62–63). For example, is it really wrong to harm an innocent human being if doing so were necessary to save 10 million people? More pertinent to the problem of r-strategists, suppose there were a human nation of stable population size with, say, an 80% infant mortality rate. Would it be wrong to interfere with the self-governance of this nation if doing so were necessary to regulate the reproductive behavior of its citizenry? If it's right to prioritize positive duties over negative duties in extreme cases like these, then AR theorists should accept that inflicting certain harms is justified in order to prevent r-strategists from giving birth to masses of doomed offspring.

In the next section, I explore a form of intervention that offers AR theorists an alternative to the regrettable zoo scenario we've discussed so far. Though turning nature into a zoo is arguably preferable to allowing unfettered r-strategist reproduction, alternative forms of intervention are themselves preferable to the zoo scenario. In particular, I explore potential applications of a new form of genetic modification called CRISPR.

5 Engineering Nature

Fallibility is a powerful constraint on any acceptable form of large-scale intervention. AR theorists who accept the desirability of intervening should nonetheless be aware of the risks and thus hesitant to advocate for any untested form of intervention. The safest move is to restrict ourselves to hypothetical endorsement, i.e., to affirm that if and when we're able to intervene without causing ecological catastrophe, then we should. Perhaps if we wait until a sufficient amount of ecological research has been done we'll have a better sense of how to intervene in nature without destroying it in the process.

[13] For his discussion of considered judgments and their role in moral theory, see Rawls's comments about 'reflective equilibrium' in Rawls 1971, 19–21 and 46–51.

At the same time, however, the extent of human fallibility should not be exaggerated. There are a lot of different ways humans intervene in nature, not all of which are ecologically destructive. Consider one such form of intervention: 'therapeutic hunting' (Varner 1998). Hunting is of course morally objectionable from an AR perspective, but it has historically been a source of ecological benefit in cases where the animal species being hunted are overpopulated. It has even lead to an increase in aggregate welfare when overpopulation threatens to lead to environmental degradation and mass starvation. Though almost any other effective means of population control is morally preferable, e.g., sterilization, the ecological success of therapeutic hunting reminds us that large-scale interventions are not doomed to lead to ecological disaster. Some large-scale interventions are both common place and ecologically beneficial.

In what remains of this paper, I'm going to explore a powerful alternative to transforming nature into a zoo. The name of this alternative is CRISPR.[14] CRISPR is a new means of genetic modification with the power to engineer wild animal populations. The following is a brief summary of its most pertinent properties:

First, CRISPR is specifically a type of gene *editing*. Other forms of genetic modification work by inserting genetic material into a cell, but they don't have any method of specifically targeting the desired genetic sequence within the genome. As a result, they run the risk of affecting other genetic sequences in unpredictable ways. Gene editing, by contrast, is able to target a specific sequence within the genome, and is thus comparatively precise (Gersbach 2014, 1009; Ledford 2015b, 22).

Second, the earlier forms of gene editing required costly materials and a considerable amount of specialized expertise in protein engineering. As a result, only a limited number of labs had the capacity to use gene editing in their research (Gersbach 2014, 1009; Doudna and Charpentier 2014, 3; Ledford 2015b, 21). CRISPR, by contrast, has comparably low material costs, and it edits the desired part of a genome via an easily modified RNA molecule (Gersbach 2014, 1009–1010; Ledford 2015b, 21). This comparative inexpensiveness and ease of use has democratized gene editing, making it possible for labs of modest means, and even amateurs called 'biohackers' (Ledford 2015a), to use gene editing in their research.[15]

Third, CRISPR-created traits can be quickly dispersed through a target population via 'gene drive'.[16] In general, the term 'gene drive' refers to the process that occurs when a gene increases its odds of being passed on. There are a number of methods via which genes may do this,[17] but the method associated with CRISPR is called an 'endonuclease drive'. Endonuclease drives occur when a gene possessed by one of a pair of chromosomes cuts the associated area of the partner chromosome. The cell, in turn, repairs the damage to the partner chromosome by copying the 'attacking' gene onto it. The gene's subsequent presence in both chromosomes ensures that it will be inherited by the nearly all of its organism's offspring (Ledford 2015b, 22; Esvelt et al. 2014, 3–4). The reason CRISPR is well-suited for implementing endonuclease drives is because it work in a similar manner: it cuts the targeted part of the genome, and this cut is in turn repaired using an edited gene. Via an endonuclease gene drive, then, CRISPR can spread a genetically engineered trait through a target population,

[14] See footnote 4.

[15] For a sampling of studies that have used CRISPR to edit genes in different species, see Bassett et al. 2013; Cho et al. 2013; DiCarlo et al. 2013; and Friedland et al. 2013.

[16] The idea of dispersing a genetically engineered trait through gene drive has been around for a while. See Burt 2003.

[17] For the types of gene drive that occur in nature, see Esvelt et al. 2014, 2–3.

and a number of studies have already done so with insects, albeit in a laboratory setting (Esvelt et al. 2014, 4–9).[18]

There are many possible large-scale applications of this technology. One possibility currently being researched is whether CRISPR can safely be used to combat malaria. As has already been demonstrated in the laboratory, modifications that reduce the number of offspring mosquitos produce or that confer resistance to malaria parasites can be inserted into a select number of mosquitos and dispersed through mosquito populations via gene drive (Gantz et al. 2015; Hammond et al. 2016).[19] And this is just one of many possible applications. Dramatic forms of physical, mental, and behavioral modification are likely to become possible through CRISPR, and with the use of gene drive, CRISPR-created traits can be dispersed with relative ease.[20]

Returning to the problem of r-strategists, contrast a CRISPR-based solution with the zoo scenario we've thus far been envisioning. In the zoo scenario, aiding r-strategists would likely involve something along the lines of the following: (a) separating r-strategist prey species from the predators that hunt them, (b) supplementing the diets of those predators in so far as they depended upon the availability of r-strategist prey, (c) sterilizing all but a small number of r-strategist individuals, and (d) caring for the offspring of those who are permitted to reproduce. In short, the zoo solution involves a tremendous amount of interference with r-strategists' liberties.

A CRISPR-based solution, by contrast, could avoid much of the interference associated with the zoo picture. For example, instead of using sterilization, it may be possible to genetically reduce the number of offspring r-strategists produce per cycle. Though a trait which performs this function would normally fail to propagate, an endonuclease gene drive, because it ensures that nearly all offspring inherit an organism's gene, is effective enough that it can be used to disperse even traits that reduce reproductive viability (Esvelt et al. 2014, 3–4). Since research done on using gene drives to affect reproduction has thus far focused on traits that prevent reproduction from occurring, e.g., infertility,[21] research on reducing clutch and litter sizes will need to be done.

Suppose that we manage to reduce the number of offspring r-strategists produce. One obvious worry is that with fewer children, r-strategist species will lose too many of their young to, for example, predation, and will end up going extinct. A second worry is that if r-strategists go extinct, the predators that prey on them will no longer have enough to eat. In light of these worries, one or more supplementary gene drives will be needed to offset the ecologically harmful consequences of reducing r-strategist birth rates. A possibility that simultaneously addresses both of the above worries is reducing predators' reliance on r-strategist prey by developing plants suitable for carnivores to eat. It might seem implausible at first blush to think that such plants could be developed, but there are reasons to be optimistic.

First, plant-based diets that are suited to the nutritional needs of carnivores are not impossible to design. Domesticated cats are carnivorous, and yet various vegan cat foods have been developed and are sold commercially,[22] and there are a number of homemade

[18] For studies that have successfully used CRISPR to conduct gene drives, see Gantz and Bier 2015; Gantz et al. 2015; and Hammond et al. 2016.

[19] For a general discussion of genetic methods for controlling mosquito populations, see Alphey 2014.

[20] For a discussion of various ways CRISPR could be used to intervene in nature, some of which are morally objectionable, see Charo and Greely 2015.

[21] See Esvelt's discussion of 'suppression drives' in Esvelt et al. 2014, 3.

[22] See the products listed at, for example, Vegan cats 2016.

recipes available. In so far as the commercial brands and homemade recipes sometimes fail to meet all of a cat's dietary needs (cats often don't get enough vitamin A or taurine), vegans have found that adding supplements is effective.[23]

Second, CRISPR has thus far been used to successfully modify a number of plants, including, for example, rice (Jiang et al. 2013), wheat (Upadhyay et al. 2013), sweet orange (Jia and Wang 2014), and liverwort (Sugano et al. 2014). It has been noted that, based on this research, there's good reason to believe that it will be easier to use CRISPR for agricultural purposes than it is to use other means of genetic modification (Doudna and Charpentier 2014, 5). Furthermore, genetic technology has already been used to create nutritionally enhanced crops, e.g., rice enhanced with vitamin A or 'golden rice'.[24] Though we won't know for sure until the necessary research is conducted, CRISPR's success with editing plant genes gives us reason to believe that it's possible to develop plants that are suitable for carnivores.[25]

One worry the reader might have about a CRISPR-based solution is that it perhaps underestimates the extent to which particular species are uniquely suited to their ecological context. Though I've already acknowledged that we must exercise caution in light of the ecological risks associated with genetically modifying r-strategists, the other side of the relationship between r-strategists and their ecosystems is the way in which the latter shape the former. In light of the influence ecosystems exert, it might be argued that any attempt to permanently remove the r-strategy will probably fail. For animals that use it, producing large numbers of uncared-for offspring is the most effective strategy for perpetuating their species in the particular environment they find themselves in. As a result, the r-strategy is likely to just reassert itself over time.[26]

Whether or not the above worry is well-founded is difficult to say at the moment. The feasibility of permanently removing the r-strategy likely depends on what traits we'll be capable of creating. If, for example, it turns out that we can reduce the amount of time r-strategists spend in a vulnerable state of infancy or if r-strategists can be given other survival-conducive traits, then eliminating the r-strategy may be possible in spite of the influence ecosystems have on species' development. But even if it turns out that creating or dispersing such traits is infeasible, the upshot would not be that we should give up on the CRISPR solution. Instead, the importance of ecological context would entail that the long term viability of modifications made to r-strategist species will, to some extent, require a more holistic approach involving supplementary modifications to their ecological context. One of the suggestions I made earlier - engineering plants that predators can eat – fits a holistic approach well. Giving predators an alternative food supply would reduce the extent to which they must rely upon hunting r-strategist infants, thereby helping to ensure that (former) r-strategists remain well adapted after being genetically modified. However, if it turns out that a highly holistic approach is necessary, fallibility is likely to be a heavier constraint. Modifying numerous features of the ecosystem within which a species is situated has a greater potential for ecological damage than just modifying the species itself (not to mention the greater financial costs), and so it's reasonable to conclude that the range of safe interventions will

23 For nutritional information about feeding cats a vegan diet, see Peden 1999.

24 For information about the use of genetic technology for nutritional enhancement, see Beyer 2010.

25 It's worth noting that it would be necessary to induce carnivores to eat the plants we develop. It may be possible to design the plants so that carnivores would be inclined to eat them, .e.g., make the plants smell and taste similar to meat. If this can't be done, however, then supplementary drives that genetically modify carnivore populations would be required to change their eating habits. I owe thanks to an anonymous reviewer for raising this complication.

26 I owe thanks to Oscar Horta for prompting me to address this worry.

be more limited. The extent of our ability to safely aid r-strategists, then, is affected by the extent to which permanently removing the r-strategy from a species requires changing the ecological context in which that species is situated.

A second worry the reader might have is that developing CRISPR traits will require inflicting significant harms on certain animals. After all, developing the traits we hope to disperse throughout the wild requires conducting genetic experiments on animal test-subjects, and such experiments can be invasive, painful, and debilitating. [27] Considering that one of the primary goals of AR advocacy is to end animal experimentation, it's understandable if many AR theorists are reluctant to endorse genetic experiments on r-strategist animals. However, the harms of genetic experimentation are not unjustified in this case, and I don't that one must be a utilitarian to think so (I myself am not a utilitarian). As I mentioned earlier, only the strictest of deontologists believe that negative duties *always* outweigh positive duties. Although it is plausible to claim that negative duties usually take priority, that priority must surely be relaxed in certain cases. And so long as we are willing to relax it with respect to humans, and not just animals, then we can advocate genetic experimentation on r-strategists without falling prey to speciesism.

Returning to my previous example, consider a hypothetical human nation whose citizens' life histories are roughly analogous to what we see among r-strategist species. Though some of the people born into this nation reach maturity and live successful lives, most (we said 80%) die during infancy. To improve the analogy, let's also say that the causes of infant death consist of starvation, exposure, etc., and that the number of infants born per generation is quite large: maybe 500 million or so. Possession of the above demographic characteristics entails that 400 million infants die painfully every generation. Assuming that education and other social means cannot be used to change the reproductive behavior of this country's citizens, and that volunteer test subjects are nowhere to be found (I assume both for the sake of my analogy), are we justified in forcing some citizens to undergo experiments that aim to genetically modify their behavior? Though I concede that different people have different intuitions about where the threshold for justified rights violations lies, it seems to me that whatever the correct threshold is, preventing the better part of 400 million infant deaths per generation is sufficient to justify forced genetic experimentation. And since many r-strategist species have even larger population sizes with even larger infant mortality rates, it would be speciesist to claim that experimenting on them is unjustified.

In conclusion, I've argued that AR theorists should adopt a fallibility-constrained commitment to intervening in the wild via CRISPR. Since aiding r-strategists in an ecologically safe manner is desirable but not presently feasible, and since CRISPR looks like an especially promising type of intervention, I think we should advocate that further research be done. CRISPR's aforementioned precision, cost-effectiveness, and ability to disperse traits through gene drive make it a powerful tool for engineering wildlife populations. We have good grounds to believe that CRISPR research, if conducted for the sake of promoting wild animals' flourishing and if guided by a cautious sense of respect for the importance of ecological safety, will one day yield viable means of assisting r-strategists.

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[27] Many thanks to Will Kymlicka for prompting me to address the harms of genetic experimentation.

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