

**Malaria, Species Value Ethics, and the Genetic Extermination of Mosquitoes:
An Evaluation of Gene-Drive Extinction as a
Solution to Mosquito-borne Illness**

by

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Abstract

Background: Malaria is a parasitic infection that spreads through mosquitoes. Recent advances in genetic engineering have created an opportunity to eliminate malaria in humans by driving mosquitoes to extinction.

Objective: The aim of this study is to evaluate the practical and ethical dimensions of this proposed artificial extinction, and serve as a primer for future discourse on the topic.

Design and Method: The research method is based on current literature and synthesis of an ongoing exploration of bioethics and associated fields. This research includes a dive into the primary fields of bioethical argument (Virtue Ethics, Deontology, and Consequentialism). The practical impacts of the proposed extinction on global ecology are also analyzed. The research question is: What are the projected consequences of inducing extinction in mosquitos through gene-drive as a method to control the spread of malaria, and are the human benefits worth the ethical precedent and environmental damage that could result from intentionally driving these insects to extinction?

Results: This author's analysis of ethical theory deems the repercussions of mosquito extinction to be too severe, unsupported by ethics or science.

Conclusions: Driving mosquitoes to extinction, while an effective means of combating malaria, is not a viable long-term solution, as it stands to create new environmental issues and requires too great a compromise of environmental and biological ethics.

Keywords: malaria, mosquitoes, gene-drive, bioethics, extinction, existence value

Chapter 1

Introduction

Malaria, a parasitic infection primarily spread among humans by mosquitoes, is one of the most dangerous diseases faced by humanity today, being involved in approximately one and a half million deaths in Africa annually (Ndebele, 2012, p.65). In an effort to combat this, a significant amount of medical research is devoted to finding a way to combat or eliminate the disease-causing parasite, as well as the insects that carry it. Historically, many methods of controlling infected mosquitoes have been examined. Still, the introduction of CRISPR-based gene-editing technology in 2012 has created the possibility for cheap and experimentally effective methods of controlling or even eliminating infected mosquitoes (Macias, 2017).

This technology is being deployed in real-world trials at the time of writing (Stein, 2021). However, the long-term consequences of such environmental change, and the ethical ramifications of directly sentencing a species to extinction, still warrant intense scrutiny. Therefore, we as a species must consider how broader gene-driving of mosquitos, in order to eliminate malaria in humans, could influence the global ecosystem, and if the intended human benefits are worth navigating the ethical quagmire of directly targeting “dangerous” or “harmful” animal species for extinction.

“What are the projected consequences of inducing extinction in mosquitos through gene-drive as a method to control the spread of malaria, and are the human benefits worth the ethical precedent and environmental damage that could result from intentionally driving these insects to extinction?” In an effort to answer this research question, this study examines this issue from the perspectives of the practical ecologist, the virtue ethicist, the moral deontologist, and the

utilitarian consequentialist through literature review and analysis in an effort to synthesize a conclusive moral perspective on this technology, and whether or not it should be deployed on a global scale, or at all. The methods section to follow, will outline the structure of ethical analysis and exploration performed. The final discussion will examine the significance of results, as well as how this information can be applied to the ongoing discussion of gene-drive, malaria treatment, and the role of mosquitoes in a world dominated by their prey.

Chapter 2

Literature Review

Scientific Perspective

In order to examine the literature more appropriately surrounding this issue, it was approached in three distinct sections, each focused on a certain perspective. The first perspective analyzed was science, particularly genetic and medical science, providing a factual foundation for the more theoretical perspectives to come.

In an article for Genetics, Unckless, Clark, and Messer (Unckless, 2017) provide a basic explanation of CRISPR as a tool in editing and manipulating genes. The CRISPR DNA sequence can be employed to precisely “cut” and “paste” genes in a cell, a process that, if targeted at an organism’s reproductive cells, can allow a trait to be carried to that organism’s offspring. Using this method, the process of gene-drive has become significantly more viable. A genetic trait is made dominant in reproduction, ensuring a majority of an edited organism’s offspring will carry the same trait. If a laboratory population of edited organisms is released into the natural population, this edited trait would eventually be present in nearly all members of the species, as wild organisms breed with the laboratory batch (and their modified offspring) and produce yet more modified offspring. Unckless et al. address the broader difficulties in using CRISPR for gene-drives and conclude that the process has significant potential for editing entire species over time. They examine the public health possibilities, as vectors of the disease may be made resistant or wholly exterminated. These possibilities are recognized as far from perfect, as once a

gene-drive batch is released into the wild, it is difficult to control and may spread or behave unexpectedly (Unckless, 2017).

Macias, Ohm, and Rasgon conducted a review of genetic approaches to the control of mosquitoes as a vector of malaria, analyzing in detail the methods that have been researched and developed throughout history. Possible technologies such as spreading transposons, artificial under dominance of genes, and the modification of the Wolbachia symbiote found in many mosquitoes are addressed, including the research that went into these possibilities. Each is ultimately found to be too inefficient or unreliable for serious consideration. The discovery of CRISPR as a potential route to modifying malaria-carrying mosquitos is found to be an answer, as the technology is reliable and cheap, warranting long-term experimentation and deeper research. Compared to the other methods discussed earlier, CRISPR and gene-drive are considered efficient, precise, and with largely acceptable risks. Macias et al. conclude that CRISPR is the most likely candidate for a genetic means of controlling malaria mosquitoes. However, it is acknowledged that serious forethought and projection will be needed if the technology is ever to be used en masse in order to manage long-term impacts (Macias, 2017).

Ethical Theory Perspective

In reviewing the literature relevant to the genetic control of malaria mosquitos, one finds that a great deal of thought has been put towards the ethical dimension of CRISPR and its theoretical uses and the ethical standing of mosquitoes considering their danger to humans. Suppose a gene drive to extinction is to be regarded as a serious possibility. In that case, one must address the ethical ramifications of deploying such a global project and the precedent set by targeting a species for extinction.

Caplan, Parent, Shen, and Plunkett (2015) began their analysis of the ethics of CRISPR by acknowledging the serious potential of the technology and why it is rightly considered a revolution in the field of genetics and gene modification. They also acknowledge that the upsides of the technology must be weighed against the valid concerns surrounding the broader impacts of using this technology at a large scale. They address the common layperson's fear of GMOs and strive to assure the reader that the issues of the use of CRISPR are much more than a public misunderstanding. The gene drive is considered to be worth studying as a method of genetic control, but one to be used only after intense scrutiny and projection, as a poorly planned modification might have significant, potentially disastrous impacts on the earth's biosphere. Caplan et al. focus on the importance of not placing CRISPR on a pedestal as a solution for all genetic problems, as any responsible use of the technology require a healthy weariness of its variables. The technology is concluded to be a revolutionary discovery but must be approached with caution (Caplan, 2015).

For the journal *Developing World Bioethics*, David Resnik analyzes the ethical dangers of modifying mosquitoes beyond just the use of gene-drive (2014). Resnik (2014) draws attention to the issues of open-air trials, which put any people in or around the test site at risk of becoming unwilling test subjects, as their local ecosystem and health might be seriously impacted if the trial is met with unexpected circumstances. Various methods of using gene-drive to control malaria in mosquitoes are examined, including species extinction and engineering mosquitoes that cannot carry the parasite that causes the disease or that actively vaccinate people they bite. All are found to be difficult to perfectly control or ethically test. A central issue in testing these methods is that animals travel, and any edited organism outside the test site could create ripples throughout the neighboring populations. Resnik (2014) determines

that to continue to research and test this technology would require serious consideration and strict regulation for both the scientists conducting the research and the lay people that stand to be impacted by it (Resnik, 2014).

In a viewpoint paper for the Malawi Medical Journal, Ndebele and Musesengwa detail the existing ethical issues in how malaria and infected mosquitoes are studied. The main issue is based on the fact that the easiest way to lure infected mosquitoes is with human bait and how junior researchers are often exposed to malaria in order to capture the insects. This practice is found to be ethically fraught and raises the question of whether it is ethical to put people at risk of malaria to learn more about it and develop ways of combating it. Ndebele and Musesengwa (2012) find that if the ultimate aim of malaria research is to save human lives, then human lives must be the top priority of the researchers, above both the environment and the research itself (Ndebele, 2012).

Moral Value Perspective

The final perspective to be addressed in the literature regarding mosquito extinction is that of the mosquito's inherent value and whether or not humanity should be allowed to destroy entire species in the name of human comfort. As this argument is ultimately subjective, no objective conclusion can be drawn, but the rhetoric and arguments are valuable to a deeper understanding of the issue.

In a now slightly dated paper, entomologist Jeffrey Lockwood (1987) examines the philosophical and evolutionary dimensions of insect extinction, especially extinction as a result of human alteration of the environment. Lockwood (1987) establishes a basic understanding of morality, including the human tendency to view an accepted moral stance as moral truth and the belief that a being must be capable of higher thought to be capable of moral standing. He brings

up the biblical understanding of humans as having innately valuable souls, and the idea that the earth was made for humanity, as well as the subsequent perception that any action taken by humans with regard to the natural world is moral, as it is ours to do with as we will. He also discusses the ethical understanding of sentience and whether a capacity for pain and suffering is a requirement for a being to be sentient and thus ethically significant. Finally, Lockwood presents evidence supporting the idea that insects can be considered sentient, including their capacity to reach pain and injury, and observe insects learning to influence their surroundings to specific ends. While Lockwood cannot conclusively prove that insects are deserving of moral standing, he does effectively counter many of the common arguments that they do not (Lockwood 1987).

In a deeper analysis of inherent worth, Espen Stabell (2019) proposes a method of finding a species “existence value,” the innate merit in something’s continued existence and preservation. Stabell addresses the human tendency to ascribe moral value to personally beneficial things, a tendency that indicates a perception of humans as of highest priority. Stabell’s proposed method involves determining existence value by finding the compromise of three viewpoints: self-regarding, where something is analyzed as valuable to an individual; other-regarding, where it is measured as valuable to humanity overall; and non-anthropocentric, where the subject is measured as valuable outside of human interests, potentially even despite. Stabell employs this method to find the value of deep-sea life, the protection of which might stifle or prevent human endeavors in mining or research. Stabell’s method applies to mosquitoes, particularly in balancing their role in the ecosystem against the suffering they inflict upon humans (Stabell, 2019).

In contrast to the previous positions, Jonathan Pugh (2017) argues against considering mosquitoes as moral beings, not to the point of supporting their extinction, but to the degree that he views them as lacking a moral aspect entirely. Pugh compares mosquitoes with the virus responsible for smallpox, arguing against the concept of life as inherently sacred. The idea that anything having inherent value outweighs the human benefit of eliminating it is contradictory, as humanity eliminated and celebrated the end of smallpox without considering its inherent value. He dismisses the idea that driving mosquitoes to extinction would be causing suffering to innocent creatures by stating that many commonly proposed methods of gene drive would not harm live mosquitos, instead simply reducing their ability to reproduce to the point that the species die off naturally. Pugh (2017) acknowledges the ideas behind the argument that gene-driving is dangerously playing god, especially the risks of unforeseen impacts to such broad changes. However, he concludes that such unknown variables are involved with any new technology and that this has never been a limit for progress before. Pugh agrees that there are serious ecological considerations to address before deploying gene drives on large scales. Still, he finds that the value of mosquitoes as a species, if any, is inconsequential when placed in opposition to preserving human lives (Pugh, 2017).

Synthesis

With this body of literature examined, one might feel overwhelmed with varying perspectives and data. Simply put, the issue is as follows: In the effort to eliminate malaria, what is our highest priority: saving human lives, preserving the stability of the environment, or viewing life as inherently valuable. Existing literature presents varied arguments in favor of all three. Still, so long as the technology exists unused and humans continue to die of what may be a

preventable disease, we must decide sooner rather than later, as choosing to do nothing is still a choice in itself.

Chapter 3

Methods

This study was designed to be qualitative and descriptive, as with any discussion of ethics, though I have used quantitative data. In order to educate and contextualize my argument, I have conducted a review of the literature surrounding the extinction of mosquitoes, examining the scientific and moral perspectives thereof. This literature was accessed mainly using the SUNY Purchase Library database, particularly as academic studies, and scientific reviews, with supplemental sources including studies discussing ethical theory relevant to mosquitoes, human-influenced extinction, and innate existence value.

This literature served to educate my argument about the answer to the following research question:

RQ: *What are the projected consequences of inducing extinction in mosquitos through gene-drive as a method to control the spread of malaria, and are the human benefits worth the ethical precedent and environmental damage that could result from intentionally driving these insects to extinction?*

Literature analysis was the primary method of research utilized, supplemented with ongoing education on relevant topics. Over the course of my independent research, I also took several courses on critical animal studies, bioethics, and the human perception of/culture surrounding death. Ideally, these methods would have been supplemented by on-site experience with patients and researchers in malaria-prone areas, as well as interviews conducted with individuals that have experience with either mosquito malaria or genetic engineering. Still, due to the ongoing travel restrictions imposed by the coronavirus pandemic, as well as the limited

timeframe available to conduct my research, I settled for literature analysis and ongoing bioethics education to influence my argument and conclusion.

I must admit to a bias in my research and conclusions, as I usually am very protective of insects in my day-to-day life. I regularly protect mosquitoes, even those currently biting me or others, and have lectured others on their value before. I have actively sought opposing viewpoints in my literature review and acknowledge that this bias, and my lack of experience with malaria or other mosquito-borne illness, will have influenced my conclusions.

My research was conducted under several limitations, both external and internal. While my ongoing education was designed to aid in my study, it prevented me from dedicating the entirety of my time to my research. What time I could commit was often broken up but unrelated or tangentially related coursework. In addition to this, I was employed throughout my research process, further restraining my time to research. In order to keep my research succinct enough to grade, I was unable to examine the full extent of how gene-editing is being used to combat parasitic infection, focusing instead on a single proposed method of combating mosquito-borne malaria. Lastly, this research was conducted with no external funding, so my resources were limited to those available through my college library database and what education was available at SUNY Purchase.

Chapter 4

Results

Synthesizing the findings from my literature review and ongoing education in bioethics, I ultimately argue against the deployment of a mosquito-extinction gene drive for various reasons based upon the scientific, ethical, and moral research conducted. While any discussion of morality is inherently subjective, and my conclusions are reflective of a life lived with (as yet) no exposure to malaria and ultimately harmless exposure to mosquitoes, I believe the sum of my research amounts to the stance that, while genetic engineering has great potential in the fight against malaria, driving vector species to extinction is not an acceptable way to do it.

As discussed earlier in this paper, there are many unpredictable factors involved in a genetic project of such a scale, from ripple effects through the global food web to the simple reality that a significant amount of time and resources could be wasted on a gene drive that ultimately does not work. From the more qualitative, ethicist perspective, the action is likewise unadvised, a conclusion I found through approaching the issue from three ethical theories I studied during my bioethics education. The first, Virtue Ethics, defined by Talbot (2012) as focused on “not what we do at a time, but what we become over time,” gauges the morality of an action based upon how it reflects the actor's virtues. While this is likely a point of contention if one disagrees with the idea of insects as capable of suffering, to execute an entire species as a shortcut to saving a portion of our own reflects a deficiency of selflessness and compassion on a macro scale. Additionally, this relates to the precedent we set concerning man-made extinction. Suppose humanity is comfortable stepping onto the slippery slope that eliminates species we find dangerous or unpleasant. The following perspective, Deontology, defined by Talbot (2012) as

stating that “certain actions are morally required or forbidden,” rejects the notion that ends can justify means and that an immoral act will always be wrong, regardless of the impacts incurred. From this perspective, man-made extinction, which is commonly considered an environmental tragedy, cannot be justified by human benefits. This thought falls in line with the previously discussed concept of existence value, wherein things that can exhibit a preference for their own continued existence through survival must be recognized as of value to themselves (Stabell, 2019). Finally, the theory of Consequentialism, which Talbot (2012) summarized as figuring that “it is only the consequences of an action that matter morally,” counters the deontological perspective, stating that the impacts are the key to determining the morality of an action. Taken at its face, this theory would support gene-drive extinction based on the direct benefits of eliminating malaria, though the environmental risks once again create a grey area of uncertainty. This theory creates the most significant room for argument, as, in the case of a successful gene-drive, the elimination of malaria is all but assured, and it is difficult to quantify the moral weight of a guaranteed positive against that of a potential negative, and it has been established that some, such as Ndebele and Musesengwa, find that human welfare is more important than that of the environment in the fight against malaria (Ndebele, 2012).

Despite the presence of grey-areas and dissenting voices of the examined scientific, virtue ethical, deontological, and consequentialist perspectives, the majority of my research does not favor the gene-driven extinction of mosquitoes as a viable method of eliminating malaria, as the environmental risks and issues of morality are not assuaged by the expected human benefits, especially while alternative methods of combating the infection exist.

Chapter 5

Discussion

Building upon the conclusion that, from both scientific and ethical analysis, an effort to eliminate mosquitoes through genetically-created extinction would be inadvisable on practical and theoretical grounds, it is essential to acknowledge that the fight against malaria continues in other forms. Similarly, dangerous diseases have been eliminated without genetic interference in the past. If our solution to mosquito-borne malaria is to be found in genetic science, even gene-drive, other methods are available. Though they come with scientific and ethical issues deserving of their dedicated studies, propositions exist for efforts to make mosquitoes simply immune to carrying the parasite that causes malaria or to make them actively vaccinate against it when they feed. To move away from this course of action is not to admit defeat but to acknowledge that some risks are too significant when acting on an ecological scale.

These findings are important to our current policy of mosquito control, as, at the time of writing, there are trials underway to perfect an extermination gene-drive that would deform female mosquitoes to prevent both feeding and reproduction, among others, and as this technology develops, so will the pressure to put it into use (Stein, 2021). Scientific regulation is shaped by policy, and in democratic nations, representatives of the people will shape the policy. If we are to properly regulate this technology and the ways it is put into use, the common person, and the politician both need to be educated on the arguments, scientific and ethical, surrounding it. Practically, a successful gene drive would offer an almost certain end to malaria in humans but risk triggering a dangerous environmental shift as the food web adjusts to the disappearance of a pollinator and prey animal. Ethically, the benefit of treating human suffering must be weighed

against both the global repercussions as well as the suffering inflicted on an entire species for no fault of their own. Whether you ultimately believe the price is fair for putting an end to malaria, or if you agree with this study's conclusion that a better alternative must be found, to take educated action on this topic, humanity as a whole must acknowledge and discuss the issue in depth.

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