

# GENE DRIVE ORGANISMS

What Africa should know about actors, motives  
and threats to biodiversity and food systems



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# Acronyms and **abbreviations**

APET	African Panel on Emerging Technologies
AU	African Union
CBD	Convention of Biological Diversity
CSO	Civil Society Organisation
DARPA	Defence Advanced Research Projects Agency
GE	Genetic Engineering
GM	Genetically Modified
NEPAD	New Partnership for Africa's Development
PR	Public relations

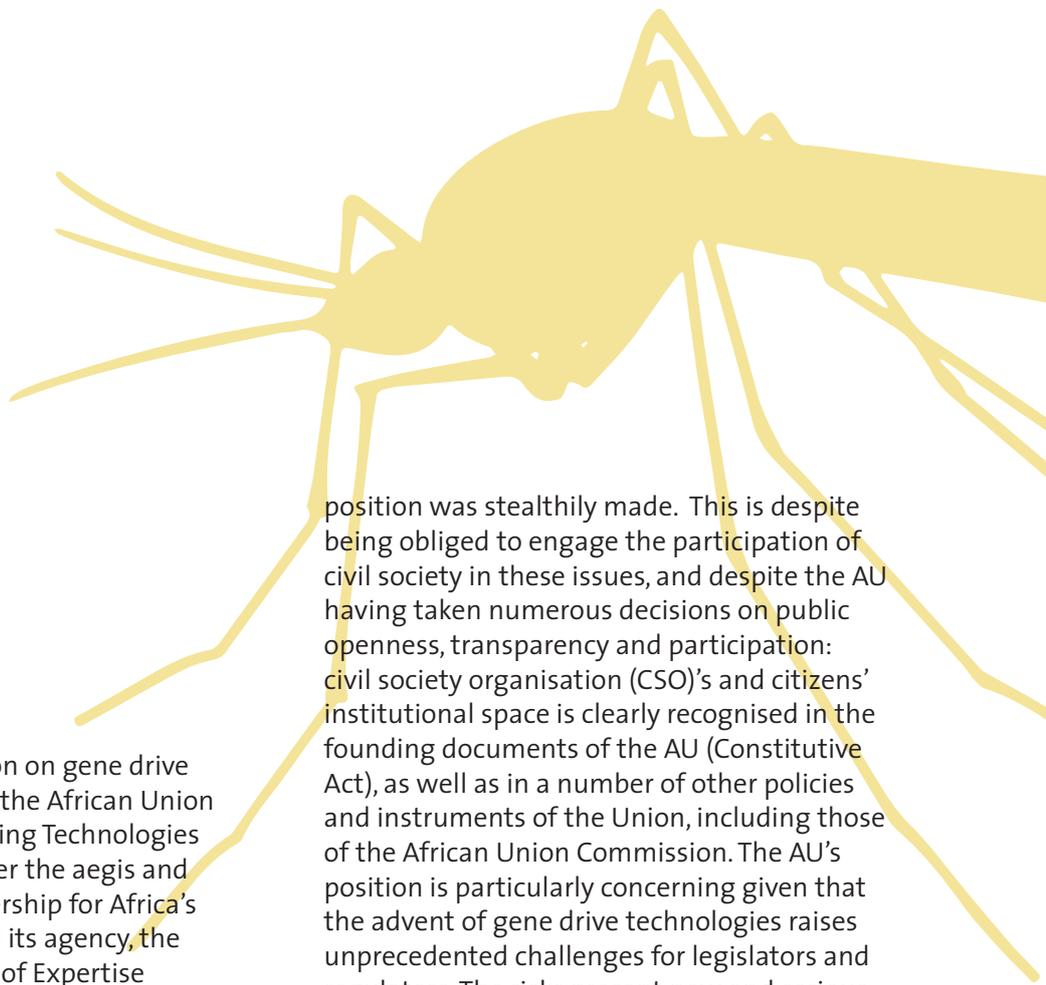


## About this **paper**

The African Union's position on gene drive technology, sanctioned by the African Union High Level Panel on Emerging Technologies (APET) and developed under the aegis and support of the New Partnership for Africa's Development (NEPAD) and its agency, the African Biosafety Network of Expertise (ABNE), is to endorse the development of gene drive technology as well as 'enabling legislation' for the deployment of gene drive technology across its member states. This position consequently became the consensus position of the Africa Group that participated in the international negotiations at the biennial United Nations Convention on Biological Diversity meeting held in Sharm el-Sheikh, Egypt, in November 2018. Indeed, Africa became a strong advocate for the advancement of gene drive technology. As far as we are aware, no consultations took place at the national levels to sanction member states of the African Union (AU) to both endorse and adopt its position on gene drives at the meeting in Sharm el-Sheikh. Rather, the AU

position was stealthily made. This is despite being obliged to engage the participation of civil society in these issues, and despite the AU having taken numerous decisions on public openness, transparency and participation: civil society organisation (CSO)'s and citizens' institutional space is clearly recognised in the founding documents of the AU (Constitutive Act), as well as in a number of other policies and instruments of the Union, including those of the African Union Commission. The AU's position is particularly concerning given that the advent of gene drive technologies raises unprecedented challenges for legislators and regulators. The risks present new and serious concerns for the conservation of biological diversity, with potential for negative effects on human health, food systems, farmers' rights and societies. These distinct challenges are not covered by any current legislation anywhere in the world.

In this briefing paper, we set out the key issues that our governments should have addressed with African civil society before endorsing positions and setting the benchmark for Africa-wide policy. In this regard, we point out that, while the impetus for the AU position might well have been gene drive technologies proposed by the Gates-funded Target Malaria consortium, as a tool to reduce the transmission of malaria on the continent,



the debate about gene drive organisms goes well beyond gene drive mosquitoes. Plans by gene drive developers target pests, pollinators, weeds and the speeding up of plant breeding programmes. The logic of using these technologies in agriculture relies on the continued deception that exceedingly complex problems in the food system in Africa can be resolved simply by new high-tech innovations, while downplaying their potential risks to biodiversity and livelihoods.

# Introduction to gene drive technologies

A new and controversial genetic engineering (GE) technology, called gene drives, are for the first time providing the means to permanently alter wild populations and ecosystems. As one of the most prominent gene drive developers, Kevin Esvelt recently stated:

**FIVE YEARS AGO, NO-ONE WOULD EVER HAVE IMAGINED THAT WE MIGHT BE ABLE TO ALTER THE TRAITS OF WILD POPULATIONS, AND BY DOING SO, CHANGE THE ASSOCIATED ECOSYSTEMS – NO-ONE. THE CONCEPT DOESN'T EVEN SEEM TO BE PRESENT IN SCIENCE FICTION.**

(Esvelt, 2018:)

Gene drive technologies are a new and powerful form of GE, specifically designed to spread an engineered, 'modified' genetic trait such as sterility throughout wild populations, with the potential to eradicate entire populations and even species. This self-propelling mechanism marks a critical distinction from standard genetically modified (GM) crops and insects that have been developed to date. Unlike standard GM organisms, where the modification is inherited approximately 50 percent of the time, gene drives skew these normal rules of inheritance so that all, or most, of the offspring inherit the

modification. While spread and persistence of transgenes from standard GM organisms into wild relatives has a high chance of eventually being diluted and lost in the population, with gene drive organisms, inheritance and spread is a prerequisite.

Though the concept of gene drives has existed for a few decades as a means for eradicating or modifying natural populations, the advent in the last decade of new GE techniques such as the genome editing tool CRISPR/Cas9 has propelled their development and turned a concept into reality (Diagram 1). Proof-of-concept gene drive organisms have already been developed in numerous organisms, including mosquitoes and mammals, with the first gene drive organism demonstrated in 2015 in yeast (DiCarlo et al., 2015), flies (Gantz & Bier, 2015), and later in mosquitoes (Gantz et al., 2015; Hammond et al., 2016; Kyrou et al., 2018) and mice (with only partial efficacy) (Grunwald et al., 2019).

The development of gene drive technologies raises unprecedented biosafety, ethical and socio-economic concerns. International, regional and national regulatory systems are currently unsuitable and inadequate in predicting and detecting risks and ensuring safety. However, a public relations (PR) campaign to gain public and regulatory support is well underway, despite the technology being in its infancy, with huge questions surrounding both risks and efficacy. This campaign includes false information circulating on the Alliance for Science website (based at Cornell University and funded by the Bill & Melinda Gates Foundation) that quotes claims that gene drives have already been released and have been effective in central America (Alliance for Science, 2018).

# CRISPR/CAS9: SECOND GENERATION GENOME EDITING TOOL

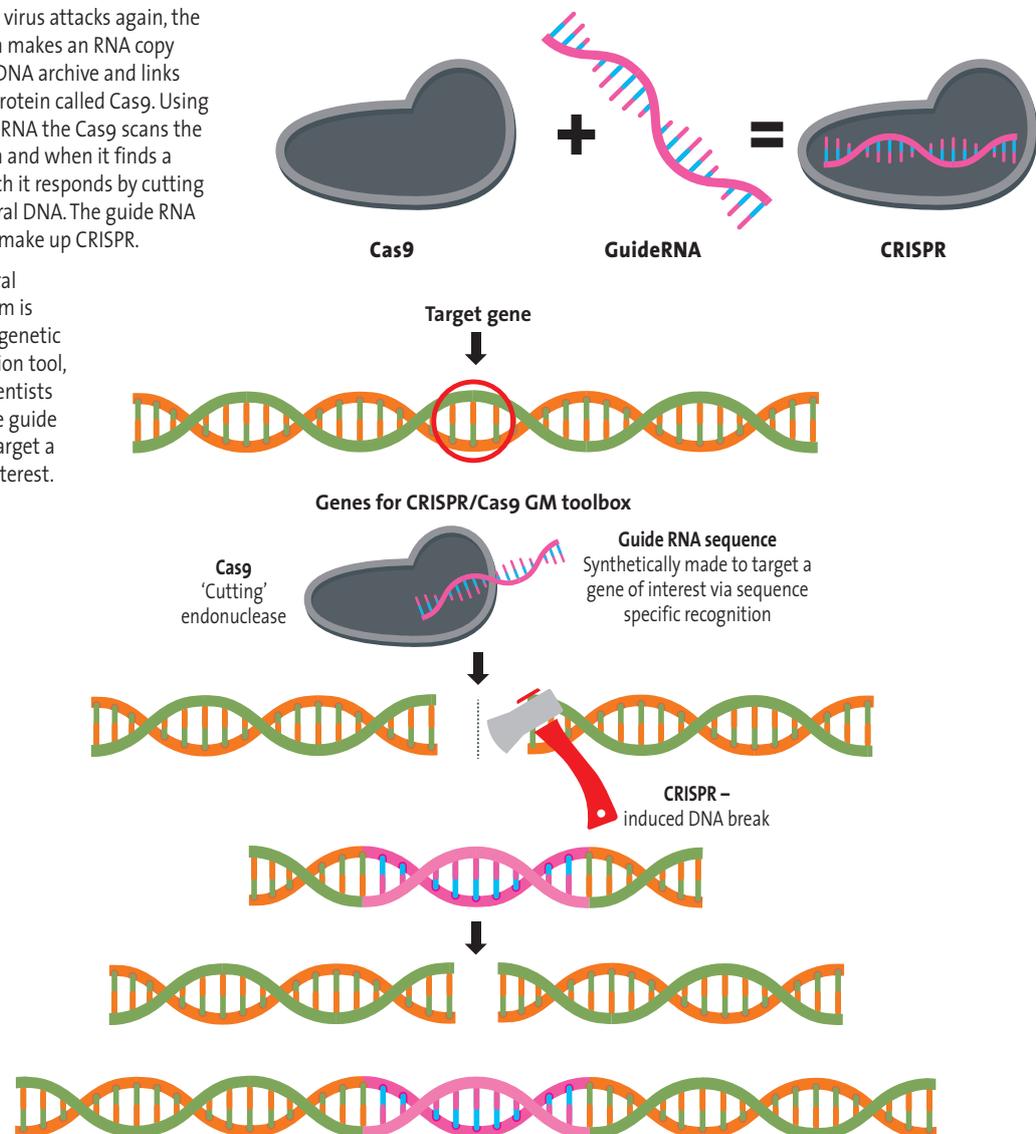
Second generation genome editing tools, such as CRISPR/Cas9, allow for a specific DNA sequence or gene to be targeted for modification

The gene-editing tool CRISPR/Cas9 uses a bacterial immune mechanism.

Viruses hunt, and insert their genetic code, into bacteria. When a bacterium survives an attack it saves a part of the viral DNA in a DNA archive called CRISPR.

When the virus attacks again, the bacterium makes an RNA copy from the DNA archive and links this to a protein called Cas9. Using the guide RNA the Cas9 scans the bacterium and when it finds a DNA match it responds by cutting out the viral DNA. The guide RNA and Cas9 make up CRISPR.

This natural mechanism is used as a genetic modification tool, where scientists synthesise guide RNAs to target a gene of interest.



## Editing a genome using CRISPR

The synthesised guide RNA is made to be a sequence that is a mirror image of the target gene to be modified.

The guide RNA and the Cas9 protein complex move along the genome, and when they find a spot where the guide RNA matches, then Cas9 makes a DNA break in the double helix. As such, CRISPR can target a DNA sequence of choice. However, it can cut in additional, unwanted regions of the genome where the sequences are also similar to the intended target site – termed “off-target” activity.

From here, the cell takes over the rest of the genetic modification process, by employing its own DNA repair pathways to re-join the DNA back together. If the cell uses the non-homologous end-joining (NHEJ) pathway to repair the DNA, this can result in:

- loss or addition of nucleotides,
- unexpected rearrangements and translocations of DNA
- destroying the function of the gene
- potentially other wider effects.

If the aim is to add/edit DNA, additional DNA templates are inserted into the DNA along with the CRISPR machinery to employ a different pathway, called homologous recombination, to allow for insertion or correct editing. However, this does not always happen, and instead NHEJ can still be employed. Gene drives attempt to push cells to employ the homologous recombination pathway, inserting the CRISPR genes into genome.

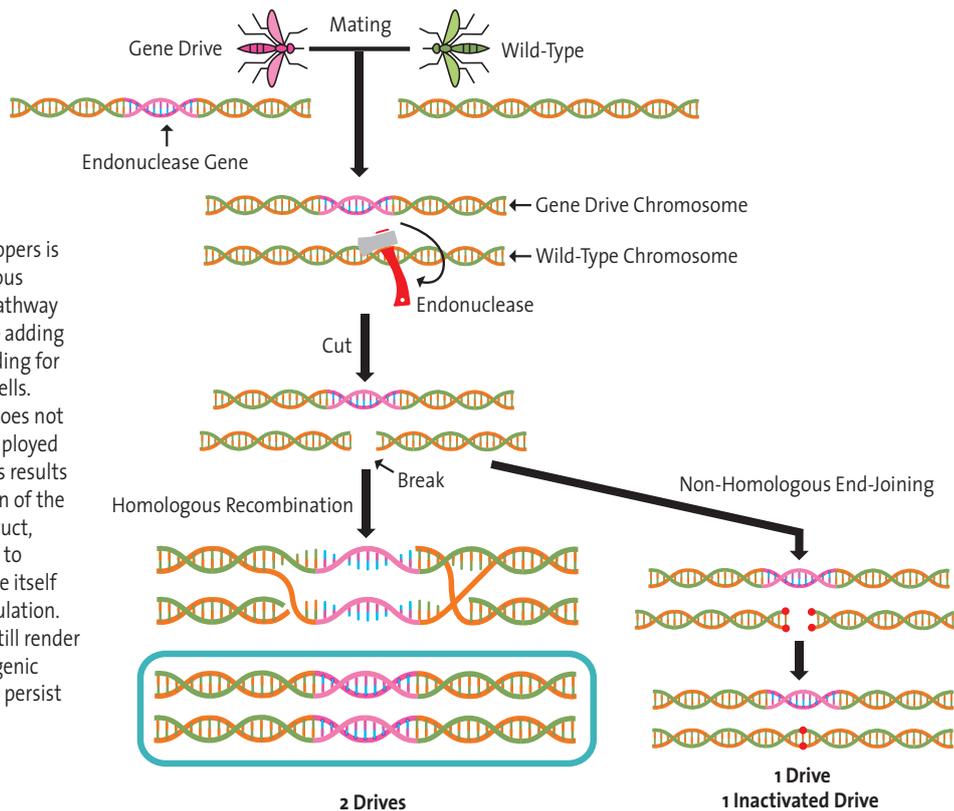
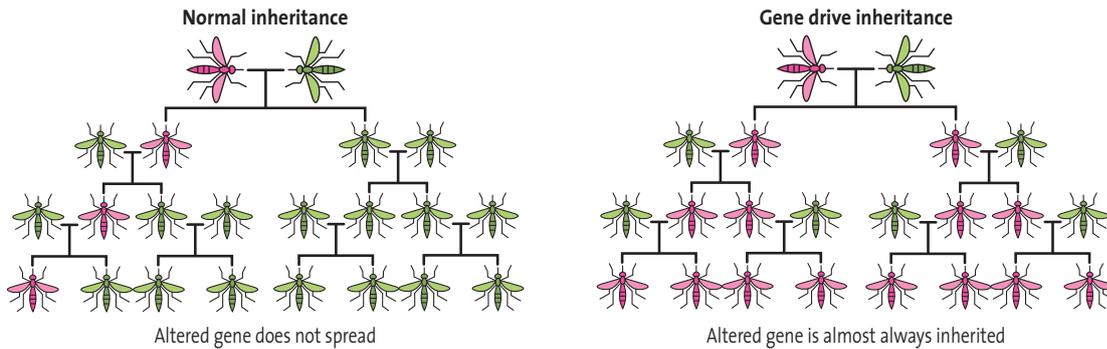
# WHAT IS A GENE DRIVE?

A new and controversial GM technology that allows for the permanent alteration of wild populations and ecosystems

Designed to spread a genetic modification through an entire population or species

Current GMOs: transgene follows standard patterns of inheritance – offspring have 50% chance of inheriting the gene

Gene drives: up to 100% of offspring can inherit the transgene/genetic modification



The aim of developers is for the homologous recombination pathway to be employed – adding in the DNA encoding for CRISPR into the cells. However, if this does not occur, NHEJ is employed instead – and this results in the inactivation of the gene drive construct, making it unable to continue the drive itself through the population. However, it will still render organisms transgenic and thus can still persist to some extent.

# How do gene drives work?

The 'driving' of a genetic trait throughout a population – the rapid spread of a modified gene and its associated trait – is achieved by inserting transgenes into an organism that code for the GE toolbox. Whereas before, GM organisms were genetically engineered in the laboratory and then released into the environment, gene drive organisms are engineered in the laboratory to carry the GE toolbox (e.g. CRISPR/Cas9), so the toolbox is then passed down to future generations, carrying out genetic engineering at each generation for perpetuity. Essentially, gene drives have now moved the laboratory to the field.

This represents a new era of GE that raises novel and unpredictable concerns about how the modified genes will behave in the wild over generations, and the lack of ability to contain them or reverse the effects, once released.

There are different gene drive designs, strategies and goals for gene drive technologies. 'Global' gene drives are those that are designed to spread throughout entire populations and currently the type that is most advanced in development. 'Localised' gene drives, in contrast, are being designed to be temporary or spatially restricted, but such strategies remain largely theoretical and yet to be demonstrated. There are also two main strategies for gene drives: those that modify characteristics in a population (e.g. affecting transmission of disease), dubbed 'population replacement' drives, versus those that are designed to eradicate populations, dubbed 'population suppression' drives.

# What are gene drives being proposed for?

Gene drive organisms have been proposed for a number of applications, including controlling disease vectors such as mosquitoes, conservation projects such as the eradication of invasive species, and for altering agricultural crop and animal traits. Military, or dual-use applications are also a concern, with the US military Defence Advanced Research Projects Agency (DARPA) reportedly the largest funders of gene drive research to date.

Deploying 'global' gene drives for disease vector eradication is being suggested as the first potential gene drive application, specifically the eradication of malaria-carrying *Anopheles* mosquitoes in African countries. The most prominent project is the Target Malaria consortium, led by Imperial College, London, which also involves additional research centres in the UK, USA, Burkina Faso, Mali, Uganda and Italy (Target Malaria, 2018).

Core funding for the project comes from the Bill & Melinda Gates Foundation, which has invested \$75 million (Regalado, 2018), as well as the Open Philanthropy Project (founded by Facebook co-founder Dustin Moskovitz) who recently awarded \$17.5 million to the project (Open Philanthropy Project). Individual laboratories also received additional funding from a variety of sources to support their work, including Department for Environment, Food and Rural Affairs (UK), the European Commission, Medical Research Council (UK), National Institute of Health (US) Ugandan Ministry of Health, Wellcome Trust (UK), Uganda National Council for Science & Technology (Uganda).

Target Malaria has been underway for four years, and is already on the ground in Burkina Faso, Mali, Ghana and Uganda, with reported activity also in Kenya. As part of their 'phased' approach, Target Malaria



Photo Credit: Martin Grandjean

plans to release gene drive mosquitoes in the third phase, following the release of non-gene drive GM mosquitoes in the first phase. The first phase was planned for 2018, with the release of 10,000 GM mosquitoes designed to be sterile, in order to reduce mosquito numbers. However, the release did not go ahead as planned, with reports of public backlashes and prominent CSO campaigns, with public and press conferences, petitions, consultations with religious and political community leaders, public marches through the capital of Ouagadougou in June 2018 (Terre à Vie, Burkina Faso, personal communication); and also reports of technical issues with the mosquitoes.

The Target Malaria consortium has developed different versions of gene drive mosquitoes. The first proof-of-principle mosquito line was published in 2016, and a newer version in 2018 that was designed to circumvent resistance development, which had been an issue with the previous version. For the first time, the mosquitoes were released into a large-scale

indoor facility in Terni, Italy in February 2019 (NPR, 2019).

As a wider part of the research, Target Malaria have recently reported a new four-year project to research and understand mosquito behaviour and dynamics in Ghana. The proposed rationale for this project is to be able to predict more accurately the role of *Anopheles* in the ecosystem and the consequences of eradicating them. Research publications also show the investigation of potential sites for trial release.

DARPA is also funding numerous laboratories for the development of gene drive technologies under the 'Safe Genes' programme, with researchers such as Kevin Esvelt at Massachusetts Institute of Technology (MIT) focusing in part on localising gene drives strategies so that they do not spread throughout an entire species, or work for a limited amount of time, though these strategies largely remain theoretical, to date. They are also looking at strategies

for reversing the effects of gene drives. The concept of localised gene drives may serve military or profit incentives, where gene drives could, in theory, be used in a targeted manner, while repetitive releases offer larger financial rewards than gene drives that are designed to spread throughout entire populations (Mitchell et al., 2018).

Leaked emails published last year also appear to show connections between DARPA and lead researchers of the Target Malaria project, though this has not been publicly acknowledged, raising serious potential concerns regarding the motivations behind the interest of the US Military in this project (Synbiowatch, 2017).

Other mosquito vectors are also being targeted for gene drive applications, including *Aedes* mosquitoes that spread Dengue, and that have more recently been linked to Zika viral infections in South America. Research is taking place at University of California, Riverside, led by Omari Akbari and also largely funded by DARPA. The TATA Trusts from India has recently donated US\$70 million to the University of California, San Diego towards gene drive research, focusing on mosquitoes for malaria eradication in India.

There are also various agricultural applications being envisaged, with quiet support from large agricultural corporations. Suggested applications include reversing herbicide resistance in weeds, livestock alterations, and suppression of pest species. As highlighted by the ETC Group (2018a), various patents exist for agricultural applications, and lobbying for permissive gene drive policy by agribusiness has already been taking place in the absence of public discussion or promotion. Development of gene drive fruit flies is already underway in the US to modify the commercially important spotted wing fruit fly, *Drosophila suzukii*, that is a major pest in North America and Europe. Gene drive medflies, a native to sub-Saharan-Africa that has spread outside the continent are also being envisaged. The lack of PR promoting agricultural gene drive applications is a deliberate strategy to avoid a repeat of the public backlash to first generation GM crops.

Conservation applications have thus far been proposed for removing invasive species such as rodents from islands in New Zealand and Hawaii, supported by organisations like Island Conservation (Island Conservation, 2018).

## What are the risks?

There are major knowledge gaps with regards to the implications of gene drives for ecosystems and human health, with research assessing efficacy and development outpacing work on potential risks and uncertainties.

The unique capacity for gene drive organisms to spread and persist in the environment raises novel biosafety and socio-economic concerns for both people and biodiversity (see Diagram 2). Once they are released, either intentionally as part of a field trial or commercialisation, or unintentionally via escape from contained conditions such as an indoor laboratory, they cannot be recalled from the environment. This opens unprecedented challenges for risk assessment, because for the first time we are faced with a GE technique whose potential ecological and health impacts cannot be adequately assessed without first deploying it. However, any deployment, even as part of a field trial, is effectively an open release that is persistent and irreversible by design, with the capacity to spread beyond the initial area. Concerns over this lack of controllability have been raised by gene drive developers who have said that gene drives are likely to be 'highly invasive' and spread to most interbreeding populations (Noble et al., 2018), warning that they are entirely inappropriate for conservation applications as a result.

The effects of modifying or eradicating whole populations or species are impossible to predict, especially when we still have limited understanding of the complexities of ecological systems and the interactions between organisms and their environments,

though experts warn of potentially serious ecological effects (Hochkirch et al., 2017). There is potential for knock-on effects on the wider ecosystem, affecting food webs such as pollinator, predator or pest numbers; niche replacement, where a new species takes over the environment left behind by an eradicated species, including, for example, another disease-carrying mosquito species; or unintentionally wiping out species that are culturally or economically important to particular regions of the world or to indigenous peoples and local communities such as an *Amaranthan* species in Central America that has been suggested for gene drive applications. Researching the role of *Anopheles* mosquitoes in ecosystems lags behind the development of the gene drive mosquitoes and the concerted efforts to influence international laws governing the technology. This is an irresponsible approach that questions the project's dedication to preventing unwanted, adverse impacts of their product.

Species eradication strategies also raise concerns over the potential to also affect non-target organisms if the gene drive transgenes spread to them. Potential mechanisms for such a scenario include the breeding of a gene drive organism with related species (outcrossing), or via horizontal gene transfer; the movement of genetic material 'sideways' between unrelated organisms (as opposed to a direct descendent). Unlike current GM organisms, outcrossing potential is much higher due to the invasive nature of gene drives, even for negative traits such as sterility, that override natural evolutionary patterns.

While there are open warnings from developers on the lack of controllability of 'global' gene drives, the proposition of eliminating malaria has been deemed as too much of a benefit to justify rejecting the technology for any potential risks. The decision on who will be the first to test the uncertainties and risks of gene drive technologies is not trivial, and serious ethical concerns are raised when top down foreign institutions and GM financiers like Bill Gates attempts to promote and influence such decisions on behalf of African countries.

Predicting potential impacts is further complicated by the fact that gene drives are effectively transferring the laboratory into natural ecosystems (Simon et al., 2018). Standard GE to date has focused on crop varieties that have been bred to behave uniformly. Gene drive releases target genetically diverse wild populations living within complex ecosystems, making it difficult to predict how the gene drive will spread and behave. Gene drives also have the capacity to erode genetic diversity as the gene drive organisms spread through a population. Unpredictable spatial-temporal dynamics of a technology that is active at every generation presents serious and potentially insurmountable challenges for risk assessments.

At the molecular level, there are several risks associated with the gene drive technologies that could also introduce unintended effects on ecosystems and people. Gene drives developed with genome editing tools such as CRISPR/Cas9 systems can introduce heritable off-target changes to the genome of the gene drive organism. Unwanted changes to DNA have the potential to alter phenotypic characteristics of organisms, such as enhancing capacity to transmit disease in the case of disease vector gene drive organisms, like mosquitoes, or altering toxicity to predators. Developers are continuing to work on improving the molecular 'precision' of genome editing tools that are incorporated into gene drive organisms. But, even if perfect precision at the molecular level can be eventually achieved, this has little reflection on the ability to control how they will behave at the ecosystem level. As raised by evolutionary biologists calling for public and ethical debates on gene drives, 'biologists who design gene drives are experts in molecular biology, without necessarily a deep understanding of community ecology or ecosystem dynamics.' (Courtier-Orgogozo et al., 2017).

Promoters of gene drives for mosquito disease vector eradication have attempted to frame the benefits versus risk discussion as one of disease eradication versus potential adverse ecological impacts, ignoring any potential harm to human health. Indeed, questions



remain regarding the potential for gene drives to complicate disease transmission and severity. Past vector eradication programmes have been associated with the ‘rebound’ effect: a resurgence in malaria cases following temporary reductions in mosquito numbers, which reduced peoples’ acquired immunity to malaria. For example, the slow recovery of mosquito populations following the cessation of pesticide programmes in the 1960s resulted in the loss of 40,000 human lives in Madagascar two decades later, occurring in the context of a collapse in control measures, such as surveillance and access to medication, as well as other exacerbating factors, such as human migration (Romi et al., 2002). This serves as a cautionary tale for gene drives releases that focus on short-term vector control techno-fixes, instead of wider determinants of malaria, and is a reminder that malaria control requires long-term holistic approaches that uplift socio-economic circumstances, access to healthcare, and implementation of surveillance programmes and environmental management systems that can efficiently prevent and monitor disease transmission.

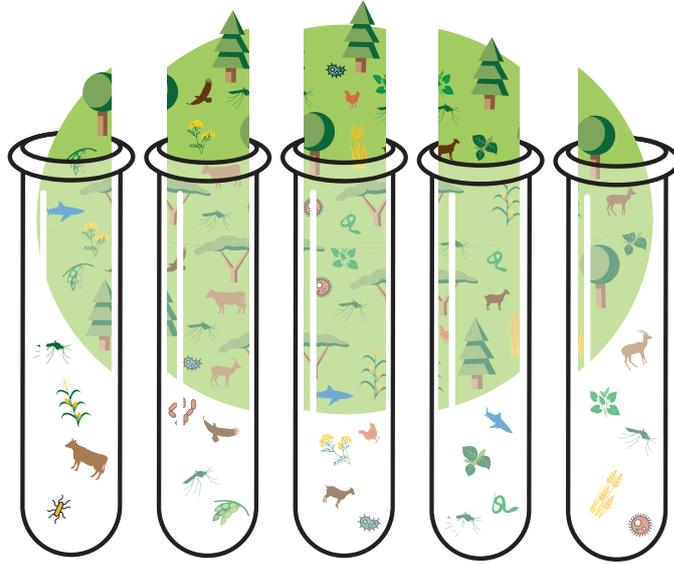
## How effective will gene drives be?

Claims that gene drives ‘present realistic options for effective disease control’ made by the African Union (AU, 2018), and media articles stating they ‘have the potential to save millions of lives’ (Vox, 2018) are circulating in the public domain in attempts to gain public support after years of distrust and rejection of GM organisms across much of the world. Under acknowledged in much of the media reporting is the fact that the technology remains in its infancy, and developers are very aware of current limitations that may hamper the efficacy of gene drives to spread properly and achieve any supposed public health or conservation goals.

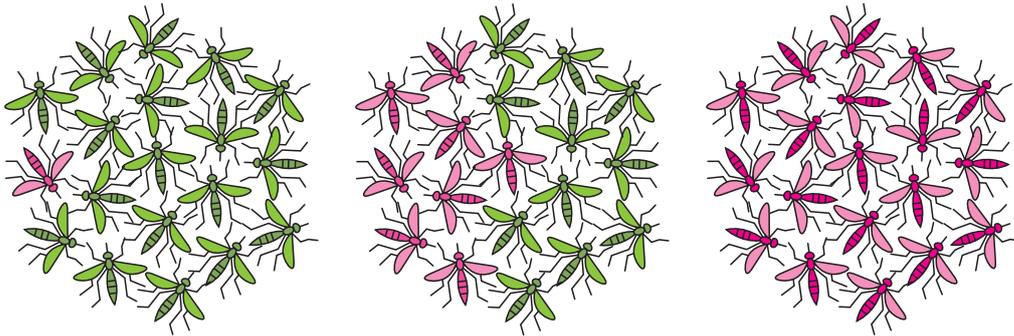
One of the major issues is the development of resistance to the gene drive construct that would prevent its continued spread through a population. Because the technology

## NOVEL FEATURES OF GENE DRIVES:

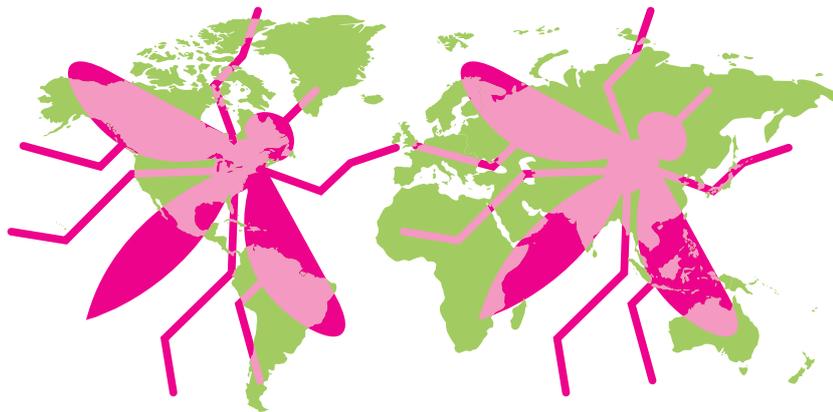
1. Transfer genetic engineering process to the ecosystem



2. Designed to spread

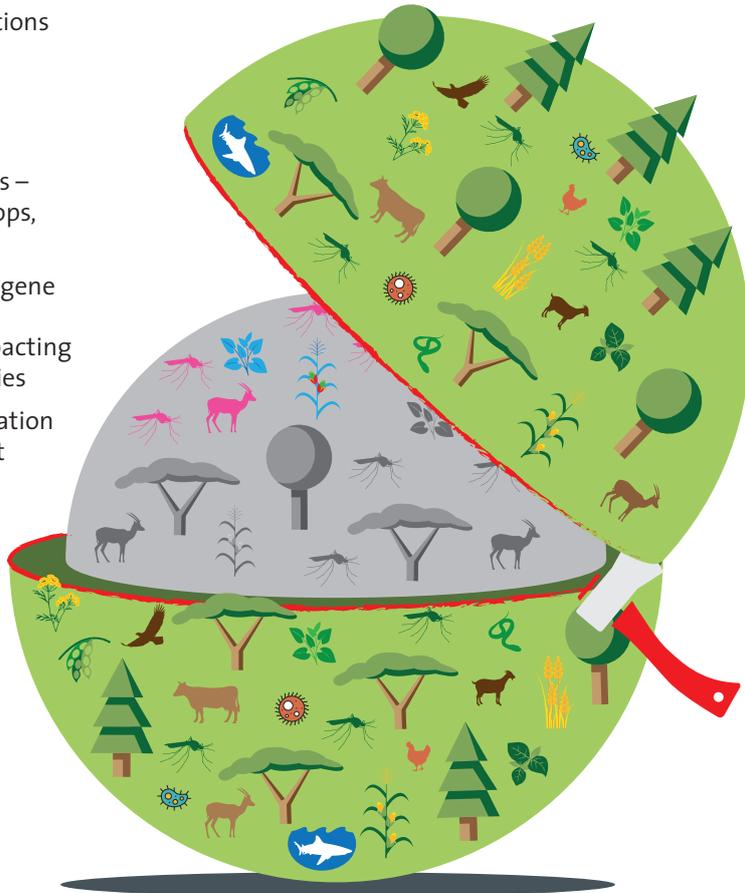


3. Modify wildlife, not cultivated species



## RISKS OF GENE DRIVES

1. Potential to wipe out populations and species
2. Reduces biodiversity
3. Niche-replacement
4. Impact on food web cascades – altering pollinators, pests, crops, interactions
5. Spread to related species via gene flow or unrelated species via horizontal gene transfer, impacting on, or eradicating other species
6. Spatial-temporal next generation effects will occur that cannot be predicted at previous generations
7. Unintended effects resulting from potential interactions with environment such as changing climatic conditions
8. Unintended effects may occur as a result of interactions with diverse, wild-genetic backgrounds



commonly relies on genome editing tools such as CRISPR/Cas9 systems that target specific pieces of DNA for modification, any mutations that may occur in the target site due to unintended mutations associated with CRISPR/Cas9 systems, could thwart its action in the next generation. New strategies (such as using multiplexed CRISPR/Cas9 systems or targeting highly conserved genes (Kyrou et al., 2018)) are being developed to circumvent this problem. However, resistance may develop in other ways, such as mutations developing within the gene drive construct itself, which are harder to overcome. Other non-molecular modes of resistance development have also been predicted for certain gene drives (Bull et al., 2019). Of note, organisms with inactivated gene drives, though no longer able to skew inheritance of the modification, will remain genetically modified, and thus will not be free

from potential adverse effects associated with standard genetic modification.

There are also limitations in how efficiently the gene drives can spread in certain organisms, particularly plants and rodents. Technical issues such as off-target effects on the genome caused by CRISPR-based system may also negatively affect the organism and thus its ability to mate.

Recent predictions by gene drive developers that have been used to promote their ability to eradicate mosquitoes and thus malaria, also envisage regular releases of mosquitoes from multiple release sites long-term (Eckhoff et al., 2017). This raises concerns about the cost effectiveness of this latest techno-fix in comparison to existing, proven measures.

## RISK OF UNINTENDED MOLECULAR EFFECTS



- Introduce heritable off-target changes to genome of gene drive organisms, which are widely associated with CRISPR technologies. This may create a new phenotype, such as an altered capacity to transmit disease or novel toxicity to a predator species that will occur at each generation and are impossible to predict.
- “Ride-along” of mutations being spread along with gene drive genetic modifications.

## Can gene drives be contained or reversed?

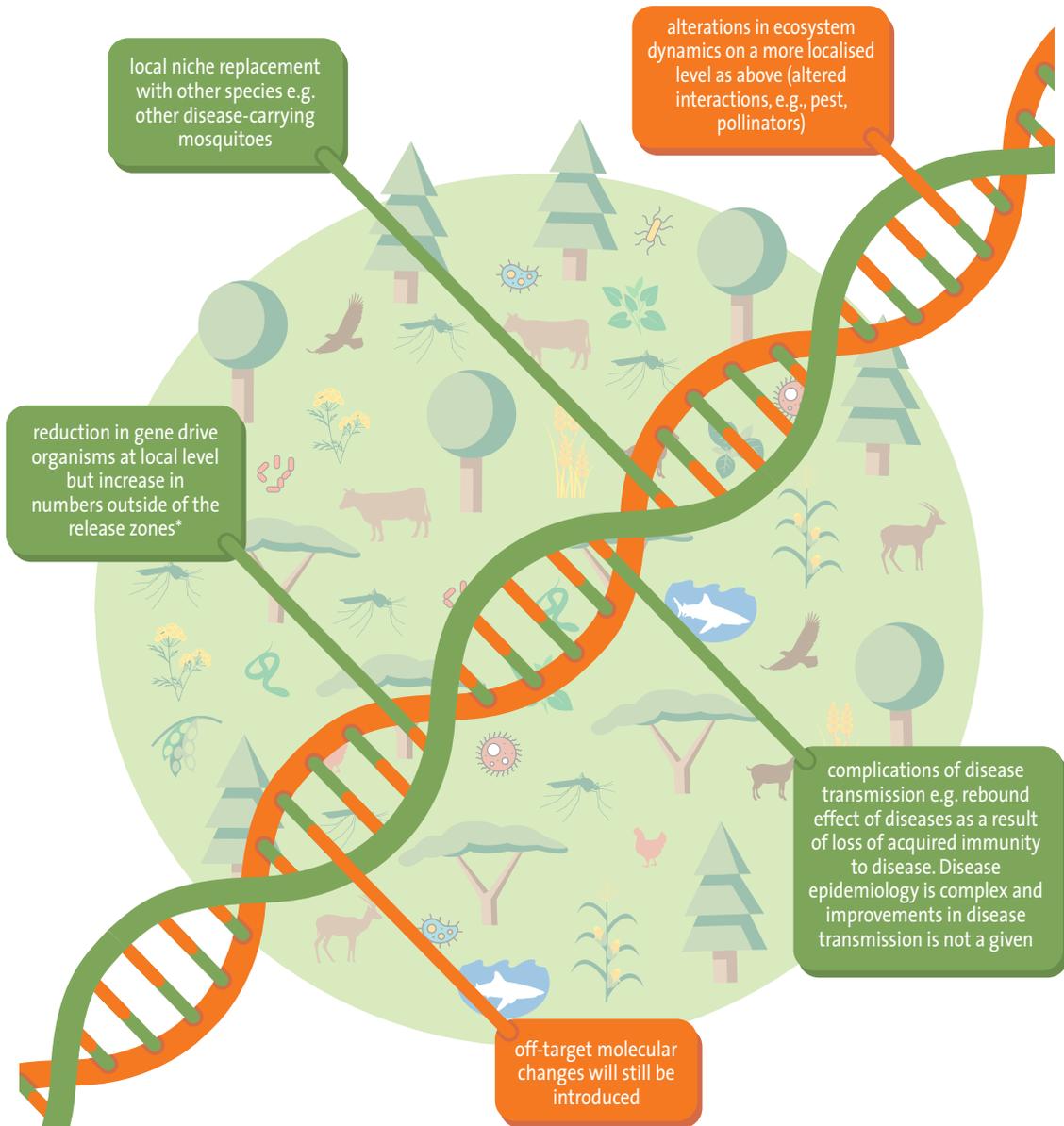
The issue of containment is a key concern for gene drive technologies, especially ‘global’ gene drives that are designed to endlessly proliferate. Strategies for remediating effects of gene drive releases, such as reversal drives – a gene drive that is subsequently released to override and thus reverse the effects of a gene drive already in the environment – are largely theoretical. They suffer from many of the limitations and uncertainties of the gene drives they are designed to undo e.g. potential for resistance development, lack of

100 percent efficiency, and off-target effects. They also leave behind genetic modification scars: even if the reversal drives render a gene drive inactive, those organisms will still be genetically modified. Other strategies for localised or temporary versions (e.g. split drives) have not yet come to fruition for mosquitoes and are not being promoted for malaria eradication.

Despite the inability to control ‘global’ gene drive spread, in attempts to gain trust from policymakers and the general public, Target Malaria is proposing a ‘stepwise’ or ‘phased’ approach to assessing the safety of gene drive technologies. This involves the transition from contained use testing in indoor laboratories, to ‘confined’ small-scale environmental trials, followed by open small and large-scale trials and finally, commercial release. However, considering their invasive nature, such a ‘phased’

## RISK OF GENE DRIVES FAILING

Temporary suppression of populations at a localised level could result in:



\*See paper: Oxitec's failed GM Mosquito releases worldwide  
<https://www.acbio.org.za/en/oxitecs-failed-gm-mosquito-releases-worldwide-forewarnings-africa-and-target-malaria-project>

approach is meaningless. As acknowledged by the African Union, the 'stages of gene drive development will likely overlap.'

Suggestions to perform 'confined' small-scale releases by implementing containment barriers, such as geographical isolation (e.g. using islands for trial locations) are

not sufficient as containment measures, as recognised by international regulatory bodies such as the Convention for Biological Diversity. Nevertheless, Target Malaria is actively investigating islands such as the Ssesse Islands in Lake Victoria as potential future trial sites (Lukindu et al., 2018).



## Why moratoria and bans on open releases of GDOs are imperative

Considering the lack of information that exists to be able to properly assess potential impacts of gene drives releases on ecosystems and human health, there is little justification for pressing ahead with releases, and conducting unpredictable experiments on the people and environments of African countries.

The recent decision by the Convention of Biological Diversity (CBD), which implements international regulations on GM organisms, imposes strict conditions on gene drive releases.

A key prerequisite is that potentially affected communities must give their 'free, prior and informed consent'. This strong global legal protection intends that local communities exercise control over, and defend their biodiversity rights in, their land and territories.

Further conditions require that precautionary, risk assessment and risk management measures are put in place to 'avoid or minimise potential adverse effects' to biodiversity. Read together with an often missed and all-important footnote, the 196 countries that are Parties to the CBD have the right to impose bans and moratoria on the release of gene drive organisms where scientific knowledge is lacking. Putting precautionary conditions in place by no means gives the go-ahead for gene drive releases, but instead points to the serious risks that might occur. There is nothing whatsoever in the text that talks about so-called benefits of gene drives — only risks.

Further, though gene drive research is ongoing with various organisms in the laboratory, no

international regulations for contained use exist. The establishment of strict conditions is vital, considering the potential for a single 'global' gene drive organism to establish itself in the environment once released. At present, since there are no regulatory measures in place for contained use of gene drive organisms inside laboratories, strict regulations are needed to prevent any unintended escapes.

## To conclude

In the African context, where little to no capacity for proper, functioning biosafety systems exist, even for first generation transgenic technologies that have been around for more than 20 years, open releases of gene drive organisms pose grave risks to the entire continent.

Under such circumstances, it is urgent that bans or moratoria laid out by the CBD are implemented under a precautionary approach that minimises harm to biodiversity and peoples' health.

Gene drive technologies are not ready for deployment, yet there have already been concerted campaigns to promote the technology as the next saviour for those suffering from malaria in Africa. An irreversible technology that can permanently alter populations and wild species has now transferred GE technologies from modifying licenced seeds to wild species for purported 'common goods', such as disease control. However, as with current GM crop commercialisations, these technologies are creating a situation where their development fails to be about the common good.

The conduct of Target Malaria's ongoing project already exposes a clear lack of transparency, with a scarcity of information provided to the public, and a lack of public consultations taking place. A recent documentary by ETC Group and Terre à Vie also challenges claims by Target Malaria that they are focused on obtaining consent from affected communities (ETC Group, 2018b), with communities stating that they were not informed on Target Malaria's plans to release GM (non-gene drive) mosquitoes as part of the first phase of their research. Unethical experiments are already taking place in Burkina Faso, which ask volunteers to expose themselves to wild-type, potentially malaria-carrying mosquitoes for paltry amounts of money (ACB, 2018). Further, the African Union has been captured by Target Malaria, and were key in influencing the Africa Group position to block moratoriums on gene drive releases at the Conference of Parties at the CBD in November 2018 (GMWatch, 2019). The CBD decision-making process has also been infiltrated by gene drive developers, raising clear conflicts of interest. The lack of focus on potential risk also raises questions with regards to how dedicated Target Malaria really is to the prevention of harm due to an eventual release of their gene drive products.

Ultimately, the decision to release gene drives must rest with the people who will potentially be affected, not those with vested interests in top-down techno-fixes that fail to move beyond the colonial medical practices and ideologies of a bygone era. Self-determination for people on the continent to practise our own solutions is a key aspect of reparatory justice and provides a path away from the corporate, neo-liberal domination of African health and food systems.

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