Gene drives may cause a revolution, but safeguards and public engagement are needed

May 5 2017, by Rachel A. Ankeny And Ary Hoffmann

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A "gene drive" occurs when a specific gene is spread at an enhanced rate through an animal or plant population.

It's something that happens in nature. Across the world, we've already seen examples of natural gene drives affecting gene frequencies in insects and mice, and the successful use of natural gene drives in changing mosquito populations to reduce disease transmission.

But new technologies such as CRISPR are enhancing opportunities for scientists to use gene drives in an applied manner.

This week, the Australian Academy of Sciences released a paper to trigger discussion around the scientific, practical, regulatory and ethical issues in anticipation of gene drives becoming a tool for controlling pests and diseases in Australia.

What is a gene drive?

Offspring normally carry two copies of a gene, one being inherited from each parent. However, this pattern of inheritance is upset by a gene drive which increases the likelihood that both copies come from only one of the parents.

If we think of genes as the "selfish" elements within a chromosome, gene drives help the most selfish element to win, and eventually to take over in a population.

Gene drives are present in nature. Transposons, also known as "jumping genes", represent an example of a natural gene drive. A transposon copies itself to different parts of the genome and becomes transmitted to offspring at a rate higher than the usual 50%.

However, while some types of natural gene drives have been used in suppressing disease transmission, potential applications have greatly expanded with the advent of synthetic gene drives. This creates new issues.

The power of CRISPR

It has recently become possible to create or synthesise gene drives via genetic engineering, using a gene editing tool known as CRISPR-Cas9.

This tool is used to link up selfish genes such as homing endonucleases (which cut DNA at specific locations) with genes targeted to be spread through a population.

When present on one chromosome, the resulting genetic construct is copied to the other chromosome through a process of being cut by the endonuclease and then repaired.

This process can potentially be used to drive almost any gene through a population. It is most likely to be effective in organisms that reproduce quickly and have a short generation time.

Although there are technical challenges to creating stable gene drives, scientific academies around the world including Australia are discussing potential applications of this technology. Safeguards that need to be put in place are also being considered. Genes that spread by themselves present some unique opportunities as well as challenges.

Why should Australia consider gene drives?

Gene drives could be especially useful in Australia for controlling pests and diseases.

We are currently engaged in a losing battle with many invasive organisms. Damage to the environment and reduced agricultural output are caused by incursions of pest mammals, insects, weeds, birds and fish.

Gene drives provide a way of potentially suppressing populations of these species and reducing damage. For example, the introduction of genes that alter sex ratios to become male biased can limit reproduction.

Drives also could be used to introduce genes that suppress the ability of vectors such as mosquitoes, ticks and midges to transmit diseases to humans and livestock, and to introduce genes that make weeds and pests susceptible to pesticides.

Use of a gene drive to eliminate a weed or pest could reduce the need for chemical spraying and potentially increase farmers' crop yields.

Safety, transparency and regulation

Because gene drives are designed to spread by themselves, stringent safeguards are needed for developing, testing and using the technology.

This is why past applications of natural gene drives involving species such as mosquitoes and European carp have involved extensive engagement with the public and regulators.

Transparency is critical, both about research on and regulation of synthetic gene drives.

Although Australia has a well established regulatory framework for gene technology, gene drives present different issues to traditional genetically modified organisms (GMOs). That's because they aim to spread new traits throughout a population, and hence may spread beyond geographical boundaries. Thus international harmonisation of regulation will be critical.

Given the range of contexts in which gene drives might be deployed, coordination will be required across a number of Australian regulatory agencies. This includes those charged with oversight of environmental, human and animal health, quarantine, and food-related issues.

Planning ahead

Gene drives may cause public concern, particularly with regard to potential unintentional ecological and environmental effects.

As has been learned from debates over GMOs and particularly about the limitations of labelling GM-free products, simply educating the public will not be sufficient. Underlying values are more important than information.

It is critical to ensure that the public is engaged on an ongoing basis about potential applications, risks and benefits of gene drive technologies in alignment with best practices for science engagement, and that funding be provided for research into these issues.

This is especially important for communities likely to be affected, such as the agricultural sector or those living close to areas where intentional release may occur.

Funding agencies can assist by providing resources to test physical containment facilities and develop molecular containment procedures such as a daisy chain system that limits the spread of a drive system.

Modelling and experiments can be used to assess the broader ecological consequences of suppressing pest populations, and research is needed to identify the risks of drives losing effectiveness due to evolution of the target species.

All of these issues need to be explored on a case-by-case basis before any decisions are made about release of drives into the environment.

The wider implications of gene drives also must be carefully assessed. For instance, a gene drive targeting pest fruit flies may be a problem for countries such as Japan, which have highly specific regulations about fruit imports.

Trade relationships with countries with limits on GMOs such as many parts of the EU and Japan could be negatively affected by use of gene drives in agriculture.

Domestic economic effects might include problems in obtaining organic certification for crops due to contact with organisms containing synthetic gene drives. Early engagement with various domestic and external stakeholders about these issues will be essential.

This article was originally published on The Conversation. Read the original article.

Provided by The Conversation

Citation: Gene drives may cause a revolution, but safeguards and public engagement are needed (2017, May 5) retrieved 26 April 2024 from https://phys.org/news/2017-05-gene-revolution-safeguards-engagement.html