

Gene Drive for Invasive Species

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Abstract: As some rodents just appear in some places where they don't belong creates unexpected harm to the people as well the other biotic organisms in the surrounding. Henceforth, the gene drive technology works as rescuer. Earlier days, toxication of rodents was the only option but now some technologies have come into the scenario which avoids unnecessary losing of the diversity and generates alternates for the same. First one is natural meiotic drive where a preferable chromosome is transmitted with unequal ratio which is generally greater than 50% , which is naturally transmitted with 50/50 ration in the offspring. Another one is clustered regularly interspersed short palindromic repeats (CRISPR) which comes under bacterial defence system. Cas9 enzyme is a protein which can cut the DNA at the specifies area dividing fit into two strands and this break can be repaired by cell's natural DNA repair mechanism. Further allowing desired modifications to occur. The above stated technologies can restrict the offsprings to be predominantly male and hence reducing the chances of further reproduction. Hence, engineered mice developed out of these technologies possesses less threat to the environment.

Gene drive technology is emerging as a potentially powerful tool in combating vector-borne diseases – notably malaria. This study introduces an agent-based model (ABM) focused on the deployment of genetically engineered mosquitoes with gene drive (GEM) in Principe Island, Republic of São Tomé and Príncipe, an island nation in the Gulf of Guinea, West Africa. Grounded in empirical data from laboratory and field studies, our model forecasts the dynamics of mosquito populations central to devising efficacious GEM release strategies. The core objective is to evaluate the time required for GEMs to constitute 90% of the mosquito population and to elucidate their dispersal throughout the island. This research is instrumental in understanding GEM potential in controlling malaria vectors.

I.INTRODUCTION

Invasive Rodents are majority found in Island areas(5% of earth's landmass) and they consists of 80% of the islands. They are omnivorous and are generally dependent only grass and grains but in

absence of the same they eat all the invertebrates, which ultimately increase the population of rodents resulting in decrease in availability of food for them. They naturally have rapid and prolific life cycles, having early sexual maturity where the juveniles grows rapidly and achieves maturity between 5 - 12 weeks. They reproduce continuously throughout the year, with females capable of producing multiple large litters annually. Having frequent reproduction allows their population to grow faster overwhelming the human settlements. These rodents causes serious harm in our ecosystem like spreading diseases, damaging crops. A study showcased that on Gough Island that, two sea bird species which were already listed in the books of endangered species, claimed that invasive rodents were behind the declining of their population. And such unusual increase in the population results in disruption in the food chain. Which further leads to environment impact. Hence rodents have possessed a big threat to the biodiversity and one such case study can be seen on a single island in New Zealand, named Little Barrier Island, where rats were such a big threat to a number of native plants, seabirds, invertebrates, and reptiles. And hence their commuting speed is fast, they can be witnessed at more places than required. Invasive Rodents are a big threat to islands with human populations as well as in agriculture sector. In Asia a lot of farmers gave faced crop damage due to rats leading to 50-100% crop damage. In homes also, they might case a lot of harm to humans as well as to the infrastructure, and hence the pest management system works well but leads to unnecessary killing of rodents. A gene drive technology will aim to disrupt their natural cycle with the help of introducing genetic modifications which affects their reproductive systems.

Although they are tiny, flying insects that are found practically everywhere in the world, mosquitoes are among the most deadly animals for people. They serve as carriers of harmful pathogens, dispersing potentially fatal illnesses like chikungunya, dengue fever, Zika virus, malaria, and yellow fever. Millions

of people suffer or lose their lives to mosquito-borne diseases every year, especially in tropical and subtropical areas. The impact has been lessened by using conventional techniques like bed nets and insecticides, but control efforts are becoming more challenging as mosquitoes adapt and become resistant. Scientists have resorted to cutting-edge genetic methods like gene drive technology and genetic modification to tackle this expanding problem. Through genetically altering mosquitoes to either decrease their population or render them incapable of transmitting diseases, and using gene drive researchers hope to significantly reduce the spread of deadly diseases and possibly save millions of lives by using gene drives to quickly spread these traits through wild populations.

II.BACKGROUND

Invasive species are responsible for over 50% of animal extinctions worldwide, causing Inland ecosystems at risk and a threat to biodiversity. These species include rats, mice and mosquitoes. Gene drive technology is emerging and has the potential in eradicating vector born diseases as well.

The Gene Drive Technology first analyze the target species and identify genes which are responsible for survival, reproduction and transmission.

The next stage where using specialized tools a “gene drive” is designed which changes the gene properties and forces that change to be inherited into the off springs.

The final stage where the modified individuals are introduced into the ecosystem, they mate and slowly the engineered trait rapidly spreads through, eradicating harms.

III.LIFECYCLE

Rats and Mice - They naturally have rapid and prolific life cycles, having early sexual maturity where the juveniles grows rapidly and achieves maturity between 5 - 12 weeks. They reproduce continuously throughout the year, with females capable of producing multiple large litters annually. Having frequent reproduction allows their population to grow faster overwhelming the human settlements. These rodents causes serious harm in our ecosystem like spreading diseases, damaging crops. A gene drive technology will aim to disrupt their natural cycle with the help of introducing genetic

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respectively), then to pupa (3 days), and finally to the adult stage, where females begin moving. Female mosquitoes follow a behavioral loop involving mating, seeking blood (for egg development), and oviposition (egg-laying), repeating this cycle up to three times. Males actively seek mates by broadcasting requests and wait for responses; if no mating occurs within a day, they move on. The mating process involves females queuing and selecting among potential mates, leading to genotype transfer. Mosquito movement across the landscape is governed by a defined flight region and optimized based on environmental resistance (e.g., elevation and land use), influencing dispersal efficiency. This model enables realistic simulation of how genetically engineered mosquitoes might interact with wild populations.

IV.THREATS TO BIODIVERSITY

Posed by invasive animals - Like humans, rodents travel commensally adapting to a range of natural habitats. Rats and mice are omnivorous, and diets typically range from grains and grasses to invertebrates. The adult animals or plants may not be affected by them, but their major effect is on eggs, young, and seeds which in future are consumed. As a result the species is effectively unable to reproduce and hence affecting the entire food web. Taking Example of an island, New Zealand 2006 where the rats were documented to threaten a number of native plants, invertebrates and seabirds. Not only this but the rodents also represent threats to lively hoods and health of humans as they are on the top of the food web and major consumers. In order to overcome the pressing human health and agricultural concerns the concept of gene drive was introduced as the threats were increasing rapidly where a farmer in Asia experienced 20 - 30% loss of crops yearly due to the rodent pests (Singleton 2003). Taking all these points in consideration, the threat to human health and agriculture have to be prioritized and to develop a regulated Gene Drive Development among the rodents. Invasive Rodents are majority found in Island areas(5% of earth's landmass) and they consists of 80% of the islands. They are omnivorous and are generally dependent only grass and grains but in absence of the same they eat all the invertebrates, which ultimately increase the population of rodents

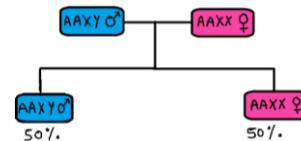
resulting in decrease in availability of food for them. A study showcased that on Gough Island that, two sea bird species which were already listed in the books of endangered species, claimed that invasive rodents were behind the declining of their population. And such unusual increase in the population results in disruption in the food chain. Which further leads to environment impact. Hence rodents have possessed a big threat to the biodiversity and one such case study can be seen on a single island in New Zealand, named Little Barrier Island, where rats were such a big threat to a number of native plants, seabirds, invertebrates, and reptiles. And hence their commuting speed is fast, they can be witnessed at more places than required. Invasive Rodents are a big threat to islands with human populations as well as in agriculture sector. In Asia a lot of farmers gave faced crop damage due to rats leading to 50-100% crop damage. In homes also, they might case a lot of harm to humans as well as to the infrastructure, and hence the pest management system works well but leads to unnecessary killing of rodents.

Mosquitoes - Certain mosquito species have spread far beyond their native ranges, mostly because of global travel and trade. Some key examples: *Aedes aegypti* (yellow fever mosquito), *Aedes albopictus* (Asian tiger mosquito), *Culex quinquefasciatus* (southern house mosquito) .These mosquitoes can: Transmit diseases to native wildlife (especially birds, amphibians, and reptiles), Outcompete native mosquitoes for breeding sites and food, Alter ecosystems — for example, by increasing disease pressure, which can reduce native animal populations.

V.GENE DRIVES

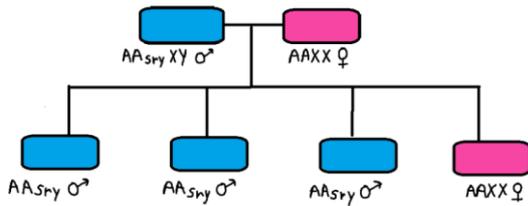
Rodents - In the present world scenario, Toxicants are the only effective technology to eradicate rodents. Superwarfarins, a highly potent rodenticide, works effectively but on the other hand it causes serious bleeding issues if ingested by humans. Unlike toxicants being lethal, genetic pest management system works as an effective alternate. The most considerable technology which got highlighted the most was Gene Drive Technology. In the present world scenario, Toxicants are the only effective technology to eradicate rodents. Superwarfarins, a highly potent rodenticide, works effectively but on the other hand it causes serious bleeding issues if ingested by humans. Unlike toxicants being lethal,

genetic pest management system works as an effective alternate. The most considerable technology which got highlighted the most was Gene Drive Technology. By manipulating a gene and adding a desired trait humans could theoretically spread the desired trait and, in the case of invasive rodents, suppress wild populations which earlier has 50% of chances of getting transmitted to the offspring. Mice are the targeted populations as it's easier to manipulate their gene as compared to rats. Mice have a chromosome 17 called the t-haplotype, which is naturally transferred to the offspring more than 50%, whereas in some variants it is even upto 90%. While mice homozygous for the t-haplotype which has 2 copies of same gene, one from mother and another from father, Heterozygous t-haplotype mice has 2 different copies of gene. Hence, the mice homozygous for the t-haplotype die before birth due to accumulated gene mutations. But tw2 variant of the t-haplotype is being used for gene drive since males homozygous for the t-haplo-type are sterile instead of dying before birth. Female tw2 homozygous for the t-haplo-type have natural fertility.



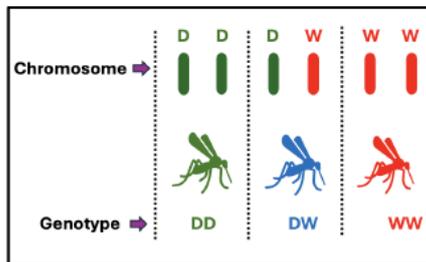
Advancement towards gene drive technology can be seen in by various institutes by stressing on Sry gene (a protein that turn on and off the genes)sequence into the t-haplotype. The Sry gene is normally located on the Y-chromosome and controls the development of male characteristics. If Sry is active, the embryo becomes male, even if it's missing or not working, the embryo becomes female, even if it has a Y chromosome. And hence, t-haplotype has meiotic drive(transmission of some gene more than half) and is located on a chromosome other than sex, in order to spread the Sry gene to both XX and XY offspring, the Sry gene has to be copied and inserted into the t-haplotype. Hence, all the offspring are phenotypically males (male physical characters) regardless of chromosomal sex.Creating more of genetically engineered mice with the Sry gene into a population of wild mice, where they could breed with wild females, could be effective in spreading the Sry gene through a population and increasing the relative proportion of male mice in a population. The Sry gene technology is currently being explored because both components naturally exist in mice and there is

a better understanding and ability to manipulate the mouse genome.



Mosquitoes - Gene drive technology is the best option to carry out particular change throughout the gene in a population. In mosquitoes, it is a but sophisticated and transmits the altered gene with a more faster rate as compared to natural transmission which is around 50:50 ratio. Gene drive technology works as a blessing in getting the desired gene 100% transferred to the offspring with assurity. CRISPR-Cas9, a molecular system that can precisely cut DNA and insert desired genetic material, is a helpful technology in getting gene altered successfully by scientist. The main goal of it is to get the undesired species of mosquitoes suppressed and get the desired gene in the mosquitoes altered by making them sterile or by significantly shifting the sex ratio in favor of males, who are not known to bite or spread illness.

The mosquito population could eventually collapse if, for example, a gene drive were created to interfere with genes essential for female fertility, resulting in fewer and fewer females being born in each generation. The population modification strategy involves genetically modifying mosquitoes to make them resistant to the viruses (such as dengue or Zika viruses) or parasites (such as Plasmodium parasites, which cause malaria).



Without lowering the number of mosquitos , these disease resistive mosquitos will propagate the resistance and will decrease the rate of disease transmission by breeding with other wild populations .Although gene drive tech has a lot of potential , it also entails serious risks and moral dilemmas . Because mosquitos are food for various other animals, ecologists are concerned that making variations in mosquito population may have

unforeseen consequences on ecosystems . There is also a worry that the gene drive might spread out of the targeted area , grow in unexpected ways or come in contact with resistance from the mosquito population. As these mosquitos travel across borders frequently , ethical concerns about consent are raised , including governance , and the global impact when releasing a self -propagating technology into the environment

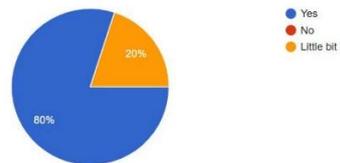
VI.REAL TIME RESULTS

Conducted a Survey of Individuals including Students, working professions, Doctors and many more for considering the very essence and ideas regarding the Gene Drive Technology

Have you ever experienced a mosquito bite?



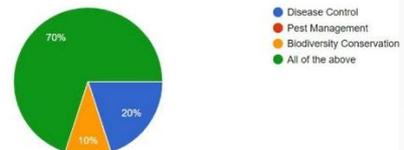
Are you aware about rodents spreading infections?



What can be a smart solution for the above problem?



What are the benefits of gene drive technology ?



Based on these results we can observe that there is a need of gene drive technology, having biological benefits, and people are aware about its effects. We all are looking forward for the development process.

VII.SOCIAL ACCEPTABILITY

The social acceptance of gene drive technology in rodents and mosquitos has been a topic of interest and has created a lot of discussion. Gene drive in mosquitos are majorly designed to prevent the spread of diseases like malaria by either reducing the population of mosquitos or by impairing their ability to transmit diseases. As the health benefits are viewed as crucial and life saving, public acceptance is typically higher where malaria is prevalent, like parts of Africa. Moral leadership, environmental effects and impact and the capacity to regulate or undo gene drive once they are started is still an important issue. Trust has been gained thanks to various communities and initiatives like Target Malaria. On the other hand, there is a lot more skepticism regarding the use of gene drive in rodents, essentially for conservation purposes like removing invasive rats and mice from island ecosystems. Many conservationists believe that native wildlife can still be protected without having to use poisons, but the public acceptance is much lower due to issues regarding changing or eradicating animal populations, unintended consequences and the drive spreading to non-target areas. Generalising this, we can say that the public has been more supportive of gene drive targeted at public healthcare issues rather than those targeted at environmental management, with strong rules and guidelines, estimated benefits and trust all roles.

VIII. CONCLUSIONS

This research paper is a case study of how gene drive can be carried out in mosquitoes to reduce the malaria and rodents which causes unnecessary impact in the highly populated human area.

A brief case study has been defined above from both perspective to understand the gene drive technology that it can further be implemented in human offsprings as well to get the desired characteristics. Hence, it provides an outlook on how the technology works rather than traditional and more disruptive methods. Using gene drive technology is beneficial in both rodents as well as mosquitoes as they require less time and their implementation is fast with respect to other various methods. Whereas it holds a lot of other repercussions aligning with environment risks, social acceptance and regulatory methods.

IX. ACKNOWLEDGEMENTS

The increasing needs of Gene Drive technology being a globally raised issue, where conferences like

Roadmap to Gene Drives: A Deliberative Workshop to Develop Frameworks for Research and Governance, February 24–26, 2016, ‘SRY Mice: An International Workshop on Invasive Rodents’, October 13–16, 2015 Emphasising the concerns and giving proposed solutions. With the motivation and curiosity to know more in this field, with the guidance of our teacher Dr, *Narendra Kumar Sura*, we were able to gain the knowledge in the Gene Development Technologies.

X. REFERENCES

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