

The Mother's Curse: An investigation into the Combined use of the Trojan Female Technique and Wolbachia in the Control of Pests

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Introduction

From the spread of disease to destruction of food crops, pests are considered the cause of countless problems worldwide. Conventional methods attempting to control these abundant and often prolific species use lethal actions such as poisons and traps to reduce the population of pests; however these methods are often inefficient, expensive to maintain over long periods, can be damaging to local ecosystems and rarely result in complete eradication. A new area of investigation, which is receiving growing support, is the management of pests through control of reproductive output, or 'fertility control' methods.

Throughout 2014, in partial fulfilment of my Honours year at the University of Otago, I produced a report on the use and efficacy of the 'Trojan Female Technique', a promising pest control method introduced in 2013^[1]. This approach utilises naturally occurring mitochondrial mutations in females that result in male offspring having greatly reduced, even non-existent, fertility, while having negligible effects on female offspring. Females and males with the mutation are coined 'Trojan females' and 'Trojan males' respectively. Since the mutation occurs in the mitochondrial DNA, it is passed down maternally, causing male offspring to be infertile and female offspring to become the next generation of Trojan females. My investigation showed that the Trojan Female Technique is very effective in reducing

pest population abundances, to zero under appropriate conditions, and keeping them low indefinitely.

Towards the end of the year I began to explore the use of this technique in conjunction with Wolbachia bacteria, an endosymbiotic bacteria commonly found in insects and other arthropods. These bacteria are also inherited maternally and are known to alter the reproductive fitness of their hosts in a number of ways. In particular, Cytoplasmic incompatibility (CI) occurs when an infected male fertilises an uninfected egg, greatly reducing the chances of that egg developing. I found that the addition of Wolbachia bacteria in conjunction with the Trojan Female Technique caused a dramatic increase in its effectiveness.

During this summer studentship I have investigated the use of the Trojan Female Technique in a specific example, applying it to a stoat population model formulated by Daniel Tompkins and Clare Veltman in 2006^[4] and updated in 2013^[3]. I also further explored the theoretical framework behind the combined use of the technique and Wolbachia bacteria.

Methods and Results

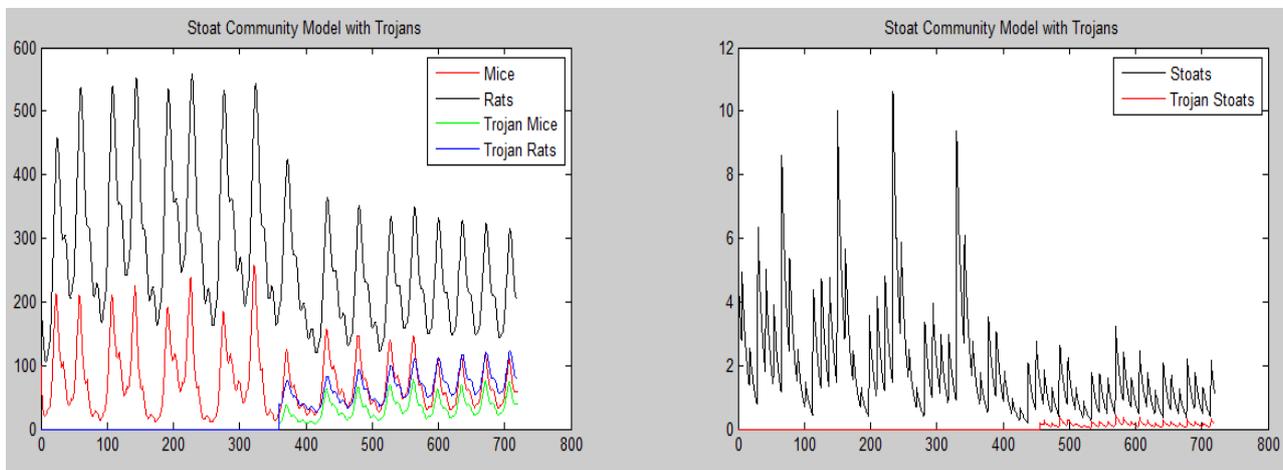
Stoat Community Model

The stoat population model introduced in [4] models the dynamics of four populations in New Zealand; stoats, rats, mice and possums. It is necessary to model them together as these populations affect each other greatly. I explored the effect of introducing Trojan stoats into the population in order to reduce stoat numbers and also the effect of introducing Trojan mice and rats in order to reduce the abundance of food available to stoats.

I found that the technique was most effective when Trojan mice and rats are introduced first followed by Trojan stoats a number of years later. The Trojan mice/rat introduction causes a drop in their respective abundances, leading to lower growth in the stoat population because of a drop in food abundance. This allows for a greater proportional introduction size of Trojan stoats, ultimately increasing its efficacy. This is a similar result to poisoning before a Trojan stoat introduction, however poisoning is only temporary and the rat and mice populations will recover fully after some time. With this method that is not the case.

Another key factor in the efficacy of this technique was the timing of each introduction. Both introductions (Trojan mice/rats followed by Trojan stoats) should be made a few years after a beech mast event. Years in which a mast occurs result in a boom in the population abundances followed by a large dip until the next mast year. Introductions should be timed so that they coincide with the dips in population abundances between mast years, again resulting in a greater proportional introduction size and hence increased efficacy.

The figure below shows an example of the behaviour of this model. Introductions occur at month 360 (mice/rats) and 456 (stoats). The introductions cause a considerable drop in the population sizes, including the peaks attained during a mast year which is when most damage to local flora and fauna occurs.



Combined Trojan-Wolbachia Model Framework

The effects of Wolbachia were taken and adapted from the model proposed in [2]. The combined model started out with 8 variables (males, females, Trojan males, Trojan females, Wolbachia males, Wolbachia females, Wolbachia-Trojan males and Wolbachia-Trojan females). I began by reducing this to 6 variables by removing the last two. This is because, unless we introduce individuals with both the Trojan mutation and Wolbachia bacteria, it is not possible for the two to be present in the same individual (in significant abundances) as both conditions are passed down maternally. Hence, under the assumption that the Trojan mutation and Wolbachia bacteria are introduced separately, I analysed the 6 variable model. I was able to further reduce this to a 3 variable model using a variable transformation. From here I could analyse the behaviour more easily.

Initial trials were very promising, with many ending in complete eradication of the pest population. The key determinant in whether the population would go extinct or just be reduced to a new, lower equilibrium turned out to be the number of Wolbachia infected individuals introduced into the population. As long as enough Wolbachia is introduced so that it spreads through the healthy (non-Trojan) population and doesn't die out, only a few Trojan mutated individuals are needed to ensure extinction. The more Trojan individuals introduced, the quicker the extinction will occur. If the critical number of Wolbachia individuals is not met the technique is still very effective in reducing the population to a new, lowered equilibrium, with greater introductions of both Wolbachia and the Trojan mutation resulting in a greater reduction in the population size.

I began to apply this combined method to *Aedes Aegypti*, the Dengue carrying mosquito, which is highly sensitive to changes in air temperature. Results so far are promising and I look forward to hearing about the continued research in this area from my supervisor Prof. David Bryant.

References

- [1] Neil J Gemmell, Aidin Jalilzadeh, Raphael K Didham, Tanya Soboleva, and Daniel M Tompkins. The trojan female technique: a novel, effective and humane approach for pest population control. 2013.
- [2] Penelope A Hancock, Steven P Sinkins, and H Charles J Godfray. Population dynamic models of the spread of wolbachia. *The American Naturalist*, 177(3):323-333, 2011.
- [3] Daniel M Tompkins, Andrea E Byrom, and Roger P Pech. Predicted responses of invasive mammal communities to climate-related changes in mast frequency in forest ecosystems. 2013.
- [4] Daniel M Tompkins, and Clare J Veltman. Unexpected consequences of vertebrate pest control: predictions from a four-species community model. 2006.