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Slow and steady wins the race: spatial and stochastic processes and the failure of suppression gene drives

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February 15, 2022

Abstract

Gene drives that skew sex ratios offer a new management tool to suppress or eradicate pest populations. Early models and empirical work suggest that these suppression drives can completely eradicate well-mixed populations, but models that incorporate stochasticity and space (i.e., drift, and founder events) often result in loss or failure of the drive. We developed a stochastic model to examine these processes in a simple 1-dimensional space. This simple space allows us to map the events and outcomes that emerged and examine how properties of the drive's wave of invasion affect outcomes. Our simulations, across a biologically-realistic section of parameter space, suggest that drive failure might be a common outcome in spatially explicit, stochastic systems, and that properties of the drive wave appear to mediate outcomes. Surprisingly, the drives that would be considered fittest in an aspatial model were strongly associated with failure in the spatial setting. The fittest drives cause fast moving, narrow drive waves that have a high chance of being penetrated by founder events, leading to failure. Our results also show that high rates of dispersal reduce the chance of failure because drive waves get disproportionately wider as dispersal rates increase. Overall, wide, slow-moving drive waves were much less prone to failure. Our results point to the complexity inherent in using a genetic system to effect demographic outcomes and speak to a clear need for ecological and evolutionary modelling to inform the drive design process.

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