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Quantifying and predicting seed dispersal from vehicles.

To better predict where new populations of plant species may occur we need to better understand ecosystem properties, propagule pressure and the plant species characteristics (Lonsdale, 1999) as well as the variability of individual species population dynamics over a heterogeneous landscape. Limited research has been conducted to evaluate the secondary dispersal distance of seed by vehicles (Clifford, 1959; Schmidt, 1989; Lonsdale & Lane, 1994; Hodkinson & Thompson, 1997; Von der lippe & Kowarik, 2007). Consequently there are few if any data on how far a seed is likely to disperse from a known source, or the probability of the seed establishing after dispersal. We have conducted research on the seed loss from vehicles and used these data to predict invasion rates across time over a spatially variable landscape.

In a controlled experiment on seed loss we placed a known amount of seed and soil slurry onto 0.1 m^2 plates that were then dried and attached to the chassis of a vehicle. Our preliminary data analysis suggested that seed loss from a vehicle driven on paved roads under wet conditions was four times greater than on dry pavement and unpaved roads in either wet or dry condition. These data were fitted to a dispersal curve (Kot *et al.* 1996, Model 4, $N = e^{(a-b\sqrt{x})}$) and the resulting model predicted that 25% of seeds were lost within 30 km and 50% by 130 km under wet conditions on paved roads. This secondary dispersal curve was added to a spatially heterogeneous population dynamics cellular automata model (Maxwell & Rew, 2010). In addition to basic population dynamics parameters (including reproduction and transition rates between seedbank, seedling and flowering plants), the model has a spatial component where seed survival to the next generation is a function of environmental suitability. In this version of the model the seeds were dispersed initially with the primary dispersal function (limited dispersal, using the form above). A second dispersal function was then fit prior to seed survival being determined according to environmental suitability. The proportion of seed which could be secondarily dispersed was set at 10 % and 2% to represent wet and dry vehicle accumulation and dispersal respectively. The underlying landscape was simple, with a linear feature (road) horizontally dissecting the 20 cell x 3020 cell landscape, with the most suitable habitat located along the road feature. Cell size represented 1 km^2. The model was run for 20 generations with all parameters held constant except the proportion of seeds available for secondary dispersal, and the model was run five times for each scenario. After 20 generations the meta-population had dispersed up to 818 km (stdev = 44.3 km) under wet conditions and 406 km (stdev = 72.7 km) under dry. The total number of cells occupied was low and mean plant density/cell was highly variable for the first 3 and 7 years for the wet and dry scenarios respectively. After 10 years density/cell began to plateau under the wet scenario but took 19 years for the dry scenario. While the details of the model cannot be fully explained here, the model does demonstrate the importance of understanding secondary dispersal by vehicles in addition to environmental suitability (Davis, 2009) for successfully predicting invasions. With additional empirical data we will be able to better predict dispersal distances under different road surfaces and conditions, and varied landscape scenarios. An improved understanding of the rate of seed loss, and distance and shape of vehicular secondary seed dispersal curves could help guide survey methods for newly invading species and development of prevention protocols.

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