# Modelling weeds and people: how today's management determines tomorrow's infestations

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**Abstract**
Unwanted plant and animal invasions throughout the world cause large negative impacts through lost natural values, lost productivity, and ongoing management costs. For instance, Australian farmers spent over $1 billion in the 2005–2006 financial year in weed prevention and management alone (Australian Bureau of Statistics). In protected areas, aggressively invasive species, like the small South American tree *Miconia calvescens*, can have similarly detrimental effects on natural reserves and biodiversity values, as has already occurred in Hawaii and French Polynesia (Meyer and Florence 1996, Medeiros *et al*. 1997, Kaiser 2006).The trend for new invasions is increasing with globalization of food production inputs and outputs, tourism travel, and faster, cheaper transport, and climate change is expected to alter the range of many current and potential invasive species, increasing the total areas affected by these problems. These observations suggest that the difficult problem of effectively managing weeds is likely to become an even larger part of effective ecosystem management in the future.

Fundamentally, invasions are difficult to manage because they deal with rapidly-changing systems well away from equilibrium. This situation is different to most managed systems simply because, in contrast to systems that are already managed, we are dealing with systems initially outside our control. Instituting invasive management requires predictions about the future in a system that we hope will change quickly and non-linearly. Because managing rapid nonlinear change is unusual and non-intuitive, one of the best ways to think about these issues is using modelling tools. Even better is to use non-standard modelling tools specifically designed to investigate non-linear rapidly changing systems

*Miconia calvescens* is known as the 'green cancer' in French Polynesia and the 'purple plague' in Hawaii. It is a small, shade tolerant tree growing 4 to 15 m (Medeiros *et al*. 1997). A plant can mature to reproduction within 4–7 years, producing small red fleshy fruits edible by nearly all rainforest frugivores. Each fruit contains nearly two hundred small seeds, and a single plant can produce up to 8 million seeds in one season. Current experiments suggest that seeds can remain viable in the soil for at least 14 years. Despite these alarmingly weedy ecological traits, there is still hope of eradication or control of *Miconia* in Australia because so far infestation is limited to a small number of sites established within the past 25 years. The hope is that effective modelling of potential spread pathways can be used to augment on-ground management to effectively control known infestations.

Modelling is a powerful way of combining our ecological knowledge of *Miconia* and the Wet Tropics rainforest to predict spread and enhance management (Murphy *et al.* 2008). We construct a model framework built on individual-based population processes incorporating maturity and fecundity data, the total dispersal kernel for *Miconia* in the Wet Tropics (Westcott *et al*. 2005, Dennis and Westcott 2007) and mortality due to density effects, habitat suitability and management actions. The model framework is completely general and can be reparameterized for any frugivore-dispersed plant. We construct two styles of model off this framework: a large-scale population model capable of following tens of millions of seeds across the landscape (see Westcott and Fletcher 2009); and an agent-based model that can follow the actions of individual on-ground management staff as they attempt to control *Miconia*.

Management modelling is important because humans remove plants from an infestation in a structured manner. Over several plant generations, these effects change the spatial distribution of the managed population. To maximize management effectiveness, we need to account for this in our weed population forecasts. We use an agent based model written in NetLOGO to study how management strategies at state, regional and individual levels combine to alter the spatial arrangement of weeds in the landscape. For instance, we can ask: with a given level of resources, should we search a small area comprehensively or a larger area more quickly? For the model system we investigated, searching a large area maximized the efficacy of weed control even when the search was not comprehensive.

Modelling provides an important way to understand complex interactions between weed population dynamics and management in our efforts to control or eradicate invasive species. In these rapidly changing highly nonlinear scenarios, intuition and linear thinking are not always the best tools for designing effective management. Non-linear models can augment traditional approaches to management to ensure that over the long term, managed populations are controlled or eradicated as effectively as possible.

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