Modelling Invasive Species and Weed impact

NZIMA Funded University of Canterbury Research Programme 2007 - 2009

Case Study 2 – Modelling the emergence of weeds in heterogeneous environments

The overarching issue to be addressed in this case study is that weeds neither invade into, nor are managed in, a homogeneous environment. Although this sounds a simple idea, the complex question generated by forecasting weed spread, detection or management in heterogeneous environments is daunting. For example, can many weed species avoid detection in some environments, and if so, what are the consequences of such "detection bias" for the long-term spread and impacts of weeds? How does environmental heterogeneity alter the optimal allocation of resources between weed detection and control? These are critical issues that both management agencies and ecologists currently face, and future progress on these issues is only possible by rigorous statistical treatment of existing data, and by using mathematical methods (e.g., individual-based modelling, percolation models) to determine how changes in weed detection, control and resources for management affect future invasions by weeds and their impacts in New Zealand systems.

Aims:
The key aims of the studentship will be to

- Formulate a model of weed spread into heterogeneous environments
- Collate existing data to underpin this model for selected invasive species.

Modelling the spread of invasive species in homogeneous environments is well established but overly simplistic for "real world" management (Higgins & Richardson 1996). The extension of weed spread models to include heterogeneous environments allows for more complex, realistic models of invasion. This case study will look at the emergence and spatial spread of invasive species in heterogeneous environments. Recent ecological developments in plant metapopulation dynamics, spatial mass effects, and the influence these processes have on species distribution and persistence can be applied to this problem (e.g., Hacker *et al*. 2001; reviewed by Freckleton & Watkinson 2002, Hastings *et al*. 2005). These processes may also control the well-documented "lag time" between when a species is introduced to a new environment and when it is perceived as an environmental weed (Sakai *et al*. 2001). This case study will explore the important area of weed emergence with a view to incorporating the results into the weed management model of case study 1 above.

Method:
Spatial models using cellular automata, percolation theory or other relevant methods will be developed with the explicit goal of understanding how environmental heterogeneity influences the spatial spread of invading populations. Alternatively, there are several recently published models that can be modified to accomplish this (e.g., Higgins *et al*. 2001, Law *et al*. 2003, Snyder 2003), or new models can be created. The student will draw on the excellent field and historical data available in New Zealand for some invasive plant species (e.g., *Buddleja davidii*, *Hieracium lepidulum*, *Pinus contorta*), and can use these data to parameterise the models and to generate biologically realistic rules as needed. Because these data have a historical component (e.g., several decades of field measurements in some cases), models can be generated from historical conditions, used to forecast and be validated against current conditions (e.g., as obtained through field work carried out within Landcare Research, the National Vegetation Survey or original field data collection). The student will benefit greatly from mentoring which includes both mathematicians and ecologists, and interactions with national and international experts in the field during the workshops and with a wide array of researchers involved in a new FRST-funded project on Ecosystem Resilience to

Weeds. The student will be expected to produce publications targeted for international journals.

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- Law, R., Murrell, D. J. and Dieckmann, U. (2003). Population growth in space and time: spatial logistic equations. Ecology 84: 252-262.
- Sakai, A.K., Allendorf, F.W., Holt, J.S., Lodge, D.M., Molofsky, J., With, K.A., Baughman, S., Cabin, R.J., Cohen, J.C., Ellstrand, N.C., McCauley, D.E., O'Neil, P., Parker, I.M., Thompson, J.N. and Weller, S.G. 2001. The population biology of invasive species. Annual Review of Ecology and Systematics 32: 305-332.
- Snyder, R. 2003. How demographic stochasticity can slow biological invasions. Ecology 84: 1333–1339.