

# Networked socioecological models for integrating agency-led and public-led invasive species incursion responses under climate change - a regional-scale analysis of the grassland weed *Nassella neesiana*

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Invasive species incursion responses are a complex interplay of ecological processes (establishment, growth, natural and human-aided dispersal), management actions (surveillance, local eradication and spread reduction) and multiple actors (central and local government, industry bodies and private citizens). Network-based simulation is increasingly used to integrate these social and ecological processes. We present an example which builds on recent advances (specifically, the impact network analysis, INA, framework) and provides unprecedented flexibility in modelling the co-evolution of invasive species incursions and management responses. The functionality we added to INA permits inclusion of habitat (e.g., climate and land use) impacts on establishment, with potential to incorporate temporal variation in habitat suitability. There is explicit provision for separate natural and human-aided dispersal processes and temporal variation in invasion threat from external sources (e.g., national, or regional border incursions). The system separates the management response into detection, local eradication, spread reduction (e.g., restricted movement of plant material and livestock, cleaning machinery and other equipment) and management adoption components. Various incursion response strategies can be explored including sentinel sites (selecting locations of higher detection probability), preventative management in locations threatened by newly discovered incursions, enforcement of hygiene or movement-restriction measures and awareness raising in target population (e.g., farmers, seed companies, garden centres). The system retains the key functionality of INA, particularly inclusion of socioeconomic network structure in modelling information sharing (about the presence of the pest and management practices). To illustrate the potential of this approach we examine the spread of a regionally restricted harmful weed, *Nassella neesiana* (Chilean needle grass, CNG). During seeding in late summer for three months of the year, the sharp seeds can penetrate animal hides and can be spread by livestock or contaminated equipment, so farmers typically do not graze these paddocks. CNG is regulated by three different regional authorities in New Zealand because of the risk to the sheep and beef sector. With CNG established in Hawkes Bay Region, we examine the biosecurity risk posed to the currently uninvaded adjacent region of Manawatu-Wanganui under current and

future climate, and with and without management of the current infestations in Hawkes Bay. Climate change increases the area potentially impacted in Manawatu-Wanganui. With the zero-management scenario in Hawkes Bay the annual incursion rate on farms in Manawatu-Wanganui eventually exceeds 12 incursions per year, while under realistic management settings in Hawkes Bay incursions decline to 0.4 events per year.