NASSELLA TUSSOCK MANAGEMENT IN NEW ZEALAND

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Abstract Nassella tussock, *Nassella trichotoma*, (Nees), was first recorded in New Zealand in the late 1800s. By the 1930s it was recognised as a serious threat to pastoral farming in the drought-prone eastern hill lands of the South Island. Legislation passed in 1946 established two nassella tussock boards that implemented, until 1990, a central government funded eradication programme of pasture renovation and annual removal of re-invading seedlings by grubbing. Records kept from 1966 until 1988 provide no evidence of eradication at the farm scale, and suggest that population decline may now have stopped (Bourdôt *et al.* 1992). In this paper we pose the questions - what intensity, frequency and type of control are sufficient to prevent nassella tussock from re-infesting the land it once occupied? We discuss how population models can help provide answers to these questions. Currently, our inadequate knowledge of the interacting demographic processes controlling population growth precludes the parameterisation of population models for nassella tussock. We outline experiments being conducted in New Zealand designed to redress this deficiency.

HISTORY OF NASSELLA IN NEW ZEALAND

Nassella tussock, an invasive perennial grass, probably arrived in New Zealand in the late 1800s (Healy 1945). Because it was easily confused with native tussocks such as *Poa caespitosa* (silver tussock) and *Festuca novae-zelandiae* (hard tussock), the seriousness of this largely unpalatable invader was not recognised until the late 1930s and early 1940s (Milne 1954, Leonard 1956). By this time it had replaced other pasture species to form virtual monocultures on many farms in Marlborough and North Canterbury (Fig. 1). Anecdotal evidence suggests that spread was very rapid during this period and at its peak, Healy (1945) approximated tussock density to be 34000 mature plants per hectare. While the perception at this time was that without immediate control measures the weed would spread further, control was often beyond the financial means of farmers.

Due to the perception of national threat and the costs involved in control, the Nassella Tussock Act was passed in 1946 resulting in the establishment of two Nassella Tussock Boards to co-ordinate an intensive central government funded control programme. From 1946 until 1990, when this funding stopped, control of dense and extensive infestations was achieved by cultivation, herbicides, destocking, topdressing, pasture renewal, afforestation, burning, grazing with cattle (Leonard 1956) and annual grubbing of scattered plants (Milne 1954). Under this strategy, populations in North Canterbury and Marlborough (Fig. 1) declined to average densities of about five and two plants per hectare on undeveloped and developed land respectively with the cost of control from 1966 to 1988 estimated at $NZ 40 million (1991 dollars) (Bourdôt *et al.* 1992). These levels are considered to be causing no economic injury. Grubbing continues today as the main control method throughout New Zealand. In Canterbury, the current annual grubbing programme, aimed at killing 98% of existing tussocks each year, is implemented on 940 infested farms at a cost of about $1.3 million year^{-1} to the rate-payers and farmers in this region (Brown Copeland Draft Report 1995). A survey conducted by the Canterbury Regional Council indicated that 13 (±7) million plants remained on these farms in autumn 1998 following the 1997/98 grubbing programme (Bourdôt and Saville 1998).

Nassella tussock was estimated to occupy 296 000 ha and 338 000 ha of pastoral land in North Canterbury and Marlborough respectively in 1988 (Bourdôt *et al.* 1992). A more recent assessment of the area of infested land in Canterbury is 265 000 ha, with the bulk of this (230 000 ha) in North Canterbury (Brown Copeland Draft Report 1995). It has been suggested that the total area infested in Canterbury represents only about 27% of the land potentially susceptible to infestation which has been estimated to be 2.1 million ha (Brown Copeland Draft Report 1995).

MODELS AS WEED MANAGEMENT TOOLS

Models are extremely useful for assisting in the understanding of the ecology of any population. One of their most basic uses is as tools for focusing research effort on critical components such as population regulation. Models help the researcher to refine and better target research questions about the system of interest, thus ensuring that scarce research funds are put to best use.

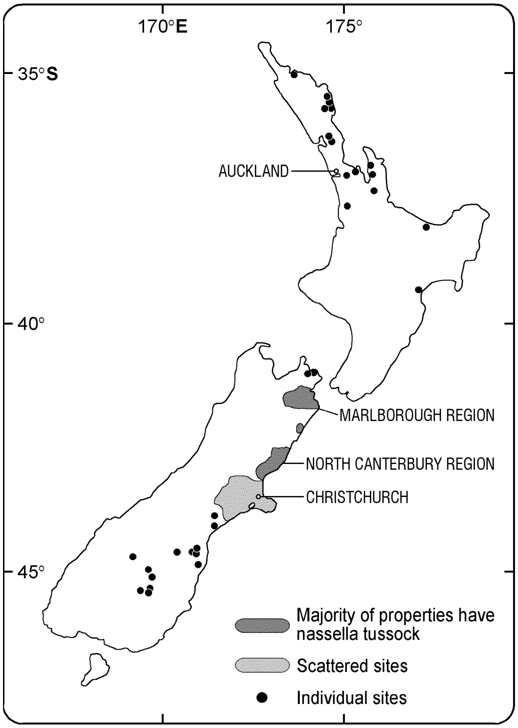

Figure 1. Distribution of nassella tussock in New Zealand (Anonymous 1986)

Models are also one of the few predictive tools available to the population ecologist interested in the management of pest species (Cousens and Mortimer 1995). It is important to understand the regulating forces and temporal variation in a pest population's growth, spread, and persistence. Once these components of the pest population are identified, different control strategies (including biological control) can be "tested" on model populations to determine optimal management strategies including timing for release of biological control agents and the intensity of control measures. In a recent study on *Hieracium pilosella* L. a simple population model revealed that mortality was the driving force in the population regulation of this weed (Lamoureaux 1998). The model was then used to explore forms of biological control that would affect reproduction and/or mortality at different times in the plant's life history. This showed that the optimal agent would be one that could either increase mortality by 10% or decrease clonal propagation by 80% (Lamoureaux 1998). With this information, researchers can focus their efforts on finding control agents that might be able to achieve these levels of control or explore integrated control "packages."

In the case of biological control, once suitable control agents are found, models can be used to predict the likely outcome and success of a specific introduction or combination of introductions. After a control agent is introduced into a field or region, models can be used to increase understanding of processes and reasons for success or failure. For example, Shea and Kelly (1998) used a stage-structured population matrix model to assess the impact of a biological control agent (*Rhinocyllus conicus* (Froelich)) and other pest management strategies for *Carduus nutans* L. (nodding thistle) in New Zealand. Using the model they found that the agent would not, on its own, cause a decline in the weed population, but showed that by using an integrated pest management approach, control was possible. They were able to determine the stages in the plant's life history that were most crucial to population growth and, as a consequence, were able to suggest different management techniques which might, when used in conjunction with the biological control agent, work as an effective integrated pest management strategy.

MODELLING NASSELLA TUSSOCK

Despite the concern about nassella tussock, and the effort directed towards its control, the population dynamics of this weed are not understood in any quantitative sense. Early qualitative accounts of the general ecology of the species in North Canterbury and Marlborough based on observations of the plant in the field and grown in containers, provided a valuable underpinning to the historical control effort (Healy 1945). More recent experimental studies in Canterbury have provided further insight into germination biology and tiller production while identifying significant knowledge gaps concerning population growth rates, seed longevity in soil, and the influence of competing vegetation on establishment and growth (Taylor 1987). Other workers have also published descriptions of the plant, control methods (Milne 1954, Leonard 1956, Beggs 1958, Leonard 1962), and anecdotal accounts of progress with control (Beggs 1958, Dingwall 1962, Leonard 1962). None of these investigations provide quantitative information on the interacting demographic processes controlling population growth in the field. As a result, questions relating to population growth and the impact of control measures arising in the weed management decision making process at both the regional and farm levels, cannot be answered with any degree of confidence.

Ecological questions of crucial importance at the regional and farm level are (1) what is the rate of population growth in the absence of intervention? (2) what is the maximum (equilibrium) density that will be reached? (3) how long will it take for a population to reach this limiting density? and, equally important (4) how do alternative control tactics influence these variables? Additionally, the influence of environmental conditions on these variables via their effects on the underlying demographic processes is important since the land within the regions containing nassella tussock are not uniformly conducive to the success of the species (e.g. sunny versus shady faces) (Healy 1945). Under (4) above, important questions are (a) what time of year should grubbing be conducted? (b) what percentage of plants must be killed? (c) which age or size classes of plants should be grubbed given that not all plants may produce seed in any given year? (d) how frequently need grubbing be carried out? and (e) what effect would a bio-control agent have?

Given recent progress in the science of weed population modelling (Cousens and Mortimer 1995, Maxwell and Sheley 1997), it is now possible to develop an objective, and scientifically credible basis, for nassella tussock management by developing and exploring the behaviour of a suitably constructed population model. Based on current understandings one such model is suggested in Figure 2. Based on some simple assumptions, the model depicts a nassella population consisting of five stages; soil seed bank and immature (non-reproductive), small, medium and large plants. During control operations, small tussocks tend to be overlooked and large tussocks are mistaken as native tussocks, hence, mature tussocks have been split into three size classes. At every time step (one year in this case) each stage can have gains (individuals entering from other stages, or by the production of seed in the case of the seed bank) and losses (movement to other stages and mortality).

Current knowledge of nassella tussock populations provide none of the quantitative information for transition rates between the proposed stages in Figure 2. Most of these are now being examined in an extensive three year (initially) field experiment in North Canterbury, New Zealand. The experiment will attempt to quantify seedling establishment and survival rates by following recruitment and mortality in permanent field plots and in plots in which seeds are sown. In addition, the experiment will examine different grubbing regimes to determine optimal timing and frequency of this control method.

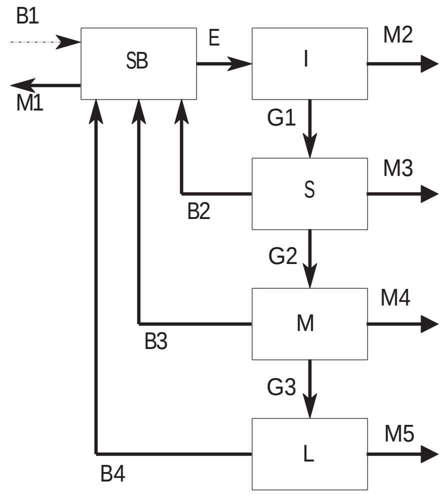

Figure 2. Population model of nassella tussock showing number of individuals in different life history classes. The five classes are the seed bank (SB), immature non-reproductive plants (I), and small (S), medium (M) and large (L) plants. The arrows indicate transitions between classes with transition symbols indicating the probability of individuals moving between classes. The probabilities G refer to growth between stages, M refers to mortality, B is recruitment to the seed bank, and E is the establishment of immature plants from the seed bank

It is anticipated that from this basic data, a robust population model can be developed which will determine significant stages in nassella's life history which should be targeted in any management strategy and help researchers in their search for possible biological control agents.

CONCLUSIONS

Nassella tussock populations have declined markedly in New Zealand over the last 3 decades during which time intensive programmes of annual grubbing have been enforced in Canterbury and Marlborough. Populations have now reached apparently stable equilibria and the goal of eradication is not being attained (Bourdôt *et al.* 1992). While some farmers believe that eradication will result from a continuation of the current control effort, others are questioning the merits of continuing along this path and object to the often very high costs of grubbing. Given this, it is imperative that we explore the regulating mechanisms of this weed and design robust control strategies that are both cost-beneficial in the long term (Denne 1988), manageable by the farmer, and that will ensure that nassella does not re-invade the pastures it once rendered useless for grazing. A population model is an essential tool in achieving these outcomes. Although a model, no matter how sophisticated, will never perfectly describe the dynamics of nassella tussock populations, it will help us understand the functioning of these populations, and help direct our efforts in selecting appropriate biological control agents and establishing integrated management strategies for this invasive grass weed.

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