

## Applications of CLIMEX modelling leading to improved biological control

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**Summary** Assessment of climatic suitability needs to be undertaken at various stages of a biological control project; from initial foreign exploration, to risk assessment in preparation for the release of a particular agent, through to selection of release sites that maximise the agent's chances of initial establishment. There is now also a need to predict potential future distributions of both target weeds and agents under climate change. The program CLIMEX<sup>®</sup> has been used in our laboratory over the past decade and we now review examples where CLIMEX has contributed to the successful prediction of agent introductions. Comparisons are made with older climate-matching methods to illustrate the progress that has been made in climate-matching methods. Limitations of climate-matching are discussed including the frequent lack of data about the agent's native geographic range and restrictions in range caused by host plant specificity.

**Keywords** Climate-matching, *Rhopalomyia californica*, *Leptinotarsa texana*, *Chiasmia assimilis*.

### INTRODUCTION

Predicting climatically suitable areas for the establishment of an introduced biological control agent is a key factor in the success of biocontrol programs.

This paper describes three instances where good climate prediction using modern methods such as CLIMEX could have contributed to better biocontrol outcomes. In all three cases the eventual establishment of the biocontrol agent verified the model's predictions.

### METHODS

The climate matching software CLIMEX Version 2 (Sutherst *et al.* 2004), which describes the response of a species to climate, was used to assess the potential distribution of three host-specific insect species on three different weed targets.

The climate profile of each insect was first determined by recursively testing various sets of parameter values until the model's distribution matched the known distribution of the species in its native range. A 10 minute climate grid was used for this purpose.

The climatic suitability of areas in Australia for each species was estimated by interpolation of Ecoclimatic Index (EI) values derived from the CLIMEX model. Areas having EI values of greater than 30 were deemed to be climatically suitable for the species, those with 10–30 are suboptimal to marginal while those having an EI of less than 10 were regarded as unsuitable.

### CASE STUDIES

**Groundsel bush** Groundsel bush, *Baccharis halimifolia* L. was considered a major weed in Queensland until its biological control became evident earlier this decade. The native distribution of this weed is in coastal areas from New York to Texas, USA. Six biocontrol agents from this area were eventually released in Australia, together with eight species collected on congeners in South America or California. The successful control of groundsel bush is now thought to be largely due to three agents: the gall fly *Rhopalomyia californica* Felt, the stem borer *Hellensia balanotes* (Meyrick) and the rust *Puccinia evadens* Hark.

The gall fly is native to California and is found in coastal areas from Santa Barbara to just north of the Oregon border, and inland to the western edge of the Central Valley. At the time of its successful release in 1982 there was serious concern that the climates may be mismatched. A comparison of climadiagrams (Walter and Lieth 1967) between San Francisco and Brisbane indicated that these areas were climatically different (McFadyen 1985) and the gall fly had been given a lower priority than other insects. However, once released in Australia, it established very quickly in coastal areas from Lismore, NSW to Bundaberg, Qld, particularly in areas such as Springbrook, Maleny and the Lamington Plateau, and gave dramatic control until parasites ultimately reduced its abundance (Palmer *et al.* 1993).

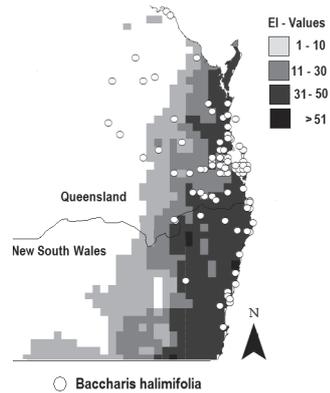
A retrospective CLIMEX model based on the native distribution indicated that most of the areas infested by groundsel bush in Australia were actually quite climatically suitable for this fly (Figure 1).

**Silver-leaf nightshade** The native range (Mexico and south-west USA) of silver-leaf nightshade, *Solanum elaeagnifolium* Cav. was surveyed to find potential biocontrol agents for the biocontrol of the weed in Australia. Several promising insect species were discovered, including the chrysomelid beetle *Leptinotarsa texana* Schaeffer (Wapshere 1988). However, when the climates of the native range and infested areas in Australia were compared using climadiagrams (Walter and Lieth 1967) it was concluded that the selected insects would not be sufficiently adapted to the summer-drought, cereal-growing areas of southern Australia where the weed was most serious and therefore the prospects of useful biocontrol were not good. No further efforts for biocontrol in Australia were made but South Africa did release agents, including *L. texana*

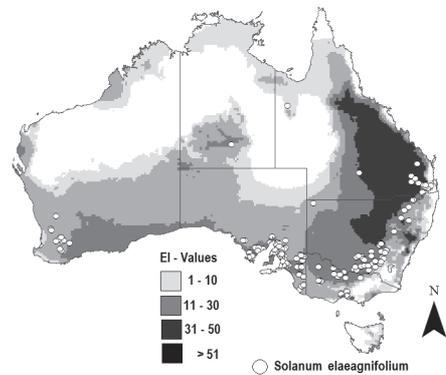
Sufficient information on the distribution of *L. texana* was obtained to build a CLIMEX model which was validated against the present distribution of the insect in South Africa. The model indicated that much of the infested areas in Australia should be climatically suitable for this insect (Figure 2). The establishment of *L. texana* in the Eastern Cape of South Africa (Olckers *et al.* 1999), where climate is very similar to southern areas of Australia, also supports the CLIMEX prediction.

**Prickly acacia** Large areas of inland Queensland and some areas of coastal Queensland are infested by prickly acacia, *Acacia (Vachellia) nilotica* subsp. *indica* and several biological control agents have been released since 1984. The most promising insect to date is the leaf feeding geometrid caterpillar, *Chiasmia assimilis* (Warren), which was introduced from Kenya and later South Africa (Palmer *et al.* 2007).

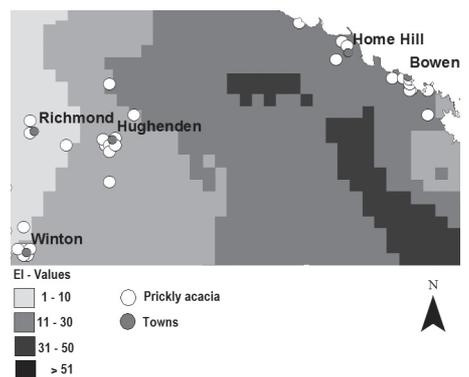
This insect was first released in numbers on the Mitchell grass downs of western Queensland in the late 1990s. It was deliberately not released in any numbers on the coast because infestations in those areas were undergoing eradication at that time. Subsequent CLIMEX modelling of the moth clearly indicated that coastal areas were climatically more suitable than inland areas (Figure 3). Renewed efforts after 2002 to establish the insect therefore included releases at coastal sites and the insect very quickly established at these sites. It then became extremely abundant between Home Hill and Bowen, causing defoliation events and even becoming a 'pest' around homestead lights. Later the insect also established at Hughenden (in the eastern edge of the inland release areas) but was never as abundant as on the coast and has not been recovered in areas to the west of Hughenden.



**Figure 1.** The distribution of *Baccharis halimifolia* in Queensland and New South Wales and the CLIMEX prediction of the climatically suitable areas for *Rhopalomyia californica* in that area.



**Figure 2.** The distribution of *Solanum elaeagnifolium* in Australia and the CLIMEX prediction of the climatically suitable areas for *Leptinotarsa texana*.



**Figure 3.** The distribution of prickly acacia in northern Queensland and CLIMEX prediction of the climatically suitable areas for *Chiasmia assimilis* in that area.

## DISCUSSION

This paper describes three instances where modern climate modelling did or would have contributed to better biocontrol outcomes than might have been arrived at by older methods.

*Rhopalomyia californica* was released despite the misgivings related to climate, which resulted in its low prioritisation. However, it is now clear that there is a relationship between its establishment in Queensland and predicted climatic suitability. Similarly with the silver-leaf nightshade project, there is now some evidence, albeit with one insect, that an apparent lack of climatic suitability of southern areas of Australia may not preclude successful biocontrol and that reconsideration may be warranted. In the case of *C. assimilis*, climate matching directly contributed to the establishment of the agent and it is very clear that there is a relationship between population establishment and predicted climate suitability.

Using CLIMEX for weed biocontrol agents is not without some problems. CLIMEX relies on knowledge of the native distribution of the organism. Very often this is not well known for potential agents, some of which may be known from a mere handful of collection sites. The importance of climate matching is such that additional exploration to determine better the natural distribution and phenology is justified. A second issue is that biocontrol agents are usually host specific organisms and therefore their distribution is dependent on the distribution of their host and climatic adaptation might be broader than appears, owing to its restriction to its host plant. In such cases, potential underestimation of where it might be able to establish in the introduced range may occur.

Despite these caveats, there is clearly a very significant role for climate matching procedures, using modern methods such as CLIMEX, in the biological control of weeds

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