# Predicting the distribution of *Emex* in Australia

**P.C. Pheloung**[A], **John K. Scott**[B] and **R.P. Randall**[A]
[A] Agriculture Western Australia, 3 Baron-Hay Court, South Perth, Western Australia 6151, Australia.
Present address: Plant Quarantine Policy Branch, Australian Quarantine Inspection Service, GPO Box 858, Canberra, ACT 2601, Australia.
[B] CSIRO Division of Entomology, CRC for Weed Management Systems, Private Bag, PO Wembley, Western Australia 6014, Australia.

## Abstract
**The potential distribution of *Emex australis* and *E. spinosa* in Australia was predicted using information on the present distribution and conditions suitable for plant growth. Two computer based systems, CLIMEX and the Agriculture Western Australia program, Climate, were used to make the predictions. The results indicate that the present distribution of *E. australis* is close to its potential, but could spread further along the south coast of Western Australia and into Tasmania. *Emex spinosa* is also widespread, but the potential distribution is considerably more than the existing distribution.**

## Introduction
The *Emex* genus is a member of the Polygonaceae family and consists of two species, *E. australis* and *E. spinosa*, native to southern Africa and the Mediterranean/Middle Eastern region, respectively. *E. australis* has naturalized in Australia, USA (California and Hawaii), India, Kenya, Madagascar, Malawi, New Zealand, Pakistan, Taiwan, Trinidad and Zimbabwe (see Shivas and Sivasithamparam 1994 for references), but is a major weed only in South Africa and Australia (Holm *et al.* 1979). *E. spinosa* has naturalized in Australia, Kenya, Mauritius, USA (California and Hawaii) (Holm *et al.* 1979), Ecuador (Brandbyge 1989), Pakistan (Siddiqi 1973) and India (Varma *et al.* 1984), but has not become particularly weedy anywhere.

Climate is a key factor which limits the potential distribution of a species, although biotic, edaphic and land management factors are also important. Climate data is well documented for most parts of the world and computer based programs have been developed to predict the potential distribution of organisms on the basis of climate. One such program is CLIMEX (Sutherst and Maywald 1985) which is used to develop a predictive model based upon the temperature and moisture requirements of a species. The model is then fine tuned to the known species distribution before being used to make a prediction to new areas.

An alternative approach, particularly where detailed biological information on the species is lacking, is to generate a prediction based only on the climate of the known distribution. The Climate System, developed by Agriculture Western Australia, adopts some of the principles of the BIOCLIM system (Nix 1986).

The results of a climate analysis can indicate where further spread of a species is possible, or provide insights towards other factors which will determine the distribution. In this paper, climate matching techniques are used to compare known against predicted distributions for *Emex* species in Australia.

## Materials and methods
A CLIMEX (Climex for Windows 1.0) model for *E. australis* was developed from the temperature requirements for growth (Weiss and Simmons 1977), the distribution in southern Africa (Scott and Way 1990) and the phenology of plant growth in southern Africa (Scott 1992, Scott unpublished). The final parameters used are listed in Table 1.

A CLIMEX model for *E. spinosa* was developed from a general model for a species associated with a Mediterranean type climate (given in CLIMEX), which was modified to match the known distribution in the Mediterranean basin (Azores, Balearic Islands, Corsica, Crete, Greece, Spain, Italy, Portugal, Sardinia and Sicily (Tutin *et al.* 1964)), Egypt, Israel, Morocco (Holm *et al.* 1979) and Libya (Siwicki 1967). The model was then further modified to include the countries of introduction, excluding Australia. Finally the model was used to predict the distribution in Australia. The final parameters used are listed in Table 1.

The Climate System uses meteorological station data from around the world. Stations within the range of the known distribution of the species were individually matched to grid points in Australia, at a spatial resolution of 0.5°. Meteorological data at the grid points were generated by the BIOCLIM system (Nix 1986). The known distribution of both species outside of Australia was used to predict the potential distribution in Australia using the Climate System. The South African distribution for *E. australis* is taken from Panetta (1990), Scott and Way (1990) and additional naturalized locations in USA (California), New Zealand, Taiwan, Kenya and Zimbabwe were based on Holm *et al.* (1979) and regional floras. Similarly, the native distribution of *E. spinosa* was taken from regional floras of the Mediterranean and Middle East regions, in addition to naturalized locations in USA (California and Hawaii), Peru and Argentina. The resultant distributions are probably not exhaustive, but representative of the climates in which the species are present and sufficiently prominent to be recorded in the literature. The actual distributions of the species in Australia are based on information supplied by Gilbey and Weiss (1980), Hnatiuk (1990) and Parsons and Cuthbertson (1992). This information was not used to generate the predicted distribution.

## Results
*Emex australis*
The world CLIMEX prediction for *E. australis* is shown in Figure 1. The Climate system produces a similar result (map not reproduced here). The known distribution is contained within the predicted range but the Mediterranean region, South America, eastern Africa and southern parts of North America also contain areas with suitable climates. In Australia, CLIMEX predicts a distribution covering most of the southern half of Australia excluding the inland deserts and mountain ranges, which fits well with the current distribution (Figure 2).

**Table 1. Parameters used for CLIMEX predictions. Parameter codes are those given in Sutherst and Maywald (1985).**

| | Parameter | *E. australis* | *E. spinosa* |
|---|---|---|---|
| Temperature | DV0 | 5°C | 10°C |
| | DV1 | 12.5°C | 16°C |
| | DV2 | 22.5°C | 24°C |
| | DV3 | 30°C | 28°C |
| | PDD | 600 | 600 |
| Moisture | SMO | 0.1 | 0.1 |
| | SM1 | 0.2 | 0.4 |
| | SM2 | 0.8 | 0.7 |
| | SM3 | 1.5 | 1.5 |
| Cold stress | TTCS | 6°C | 0°C |
| | THCS | 0.002 | 0.005 |
| | DTCS | | 15 |
| | DHCS | | 0.001 |
| Dry stress | SMDS | 0.1 | 0.02 |
| | HDS | 0.0005 | 0.05 |
| Wet stress | SMWS | 1.2 | 1.6 |
| | HWS | 0.001 | 0.0015 |
| Hot/wet stress | TTHW | 23°C | 23°C |
| | MTHW | 0.8 | 0.5 |
| | PHW | 0.03 | 0.075 |

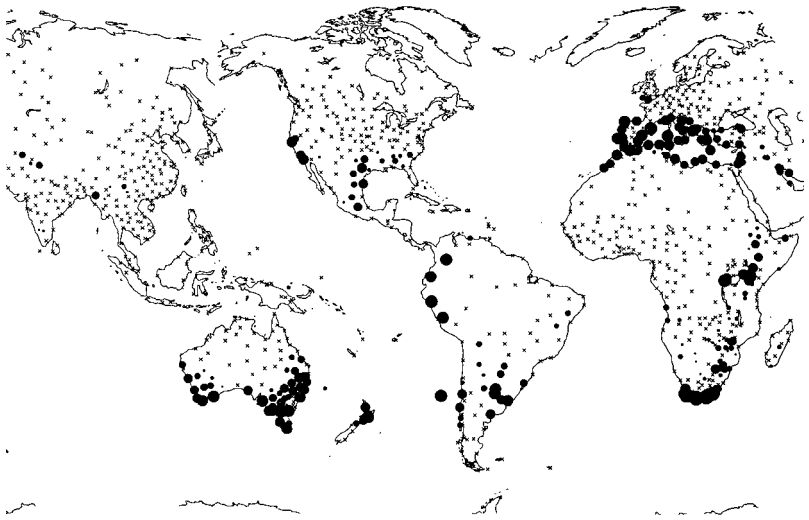

**Figure 1. Prediction of world distribution of *E. australis* by CLIMEX. The larger the circle, the more suited the site is for growth of *E. australis*. Crosses indicate unsuitable sites.**

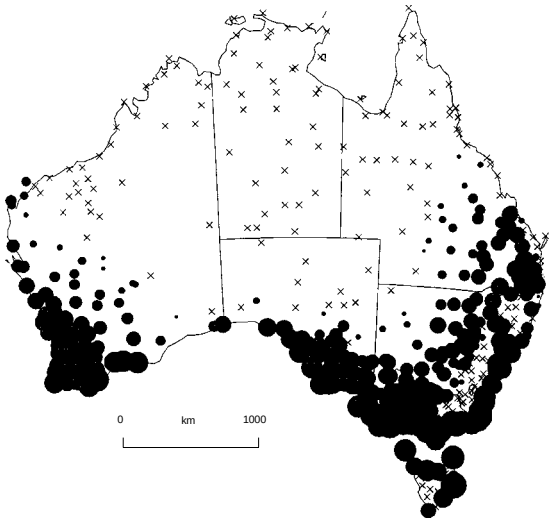


**Figure 2. Prediction of Australian distribution of *E. australis* by CLIMEX.**

The potential distribution of *E. australis* in Australia, as predicted by the Climate System, is shown in Figure 3. All of southern Australia, much of northern Queensland and coastal parts of north-western Australia may be climatically suitable. However, as with the CLIMEX prediction, the more favourable areas tend to be further south with highest matching areas in southern and south-western Australia. The actual distribution is enclosed by the predicted distribution except, for the northern reaches of the distribution in Western Australia.

*Emex spinosa*

The world CLIMEX prediction for *E. spinosa* is shown in Figure 4. The Climate system produces a similar result (map not reproduced here). The known distribution is contained within the predicted range but parts of South America, South Africa, Mexico and Australia also contain areas with suitable climates. In Australia, CLIMEX predicts a distribution similar to, but less extensive than that of *E. australis* (Figure 5).

The potential distribution of *E. spinosa* in Australia, as predicted by the Climate System, is shown in Figure 6. South and south-western Australia are the most climatically suitable. Its recorded distribution is enclosed by the predicted distribution.

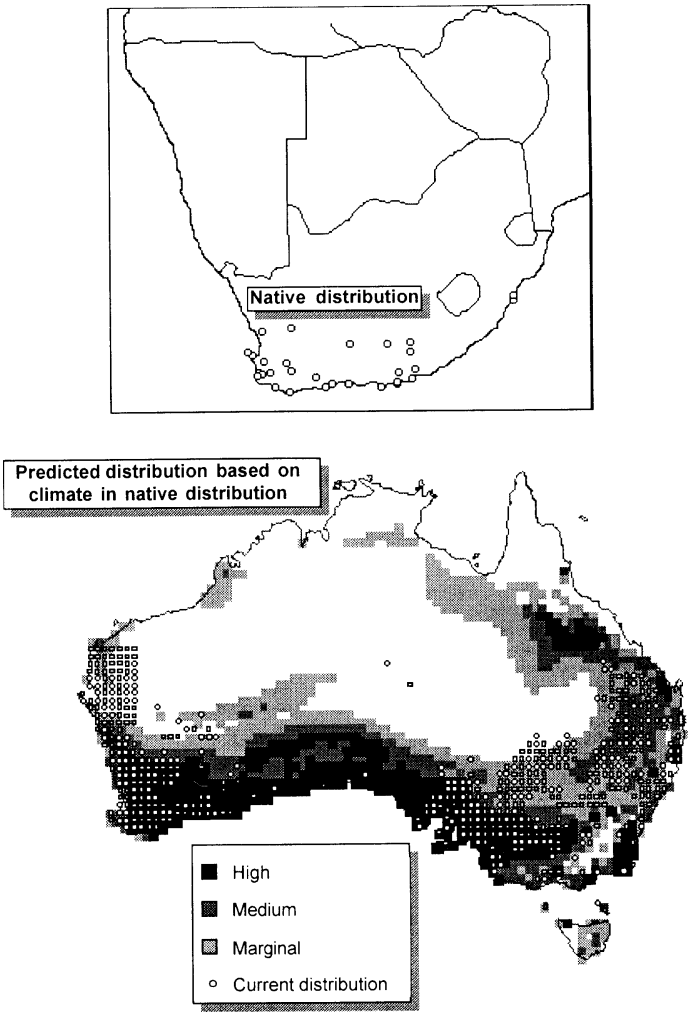


**Figure 3. Prediction of Australia distribution of *E. australis* by Climate System. Locations within the native distribution in South Africa (shown) and additional naturalized locations outside of Australia were used to generate the prediction.**

## Discussion

The native distributions of the two *Emex* species are quite distinct and do not overlap, although both species have become naturalized in other areas with temperate climates, such as California, Hawaii and southern Australia.

*Emex australis* is climatically well suited to temperate Australia and this is confirmed by the actual distribution (Figure 3). It is a weed of areas subject to disturbance and is not normally found in natural ecosystems in Australia (Keighery 1996). Worldwide, the species is suited to growing in many areas (Figure 1), but the actual distribution is much more restricted. Outside Australia, the species has not become particularly weedy where it has naturalized. Presuming that the species has had adequate opportunities to become established, other factors such as the soil type or land management may not be appropriate or pests of Polygonaceae may be active and restrict the proliferation of the species in the climatically suitable areas.

*Emex spinosa* is widely regarded as a minor weed (Holm *et al.* 1979). Although well suited to the climate of southern Australia, and south-western Western Australia in particular, the actual distribution is limited to a few small areas (Figure 6). The reasons for this are unclear. *E. spinosa* is more competitive than *E. australis* in pot experiments (Weiss 1977) and the author of that study suggested that *E. spinosa* may well displace *E. australis* as the dominant species where the two co-exist. Nevertheless, after nearly 20 years *E. australis* continues to predominate.

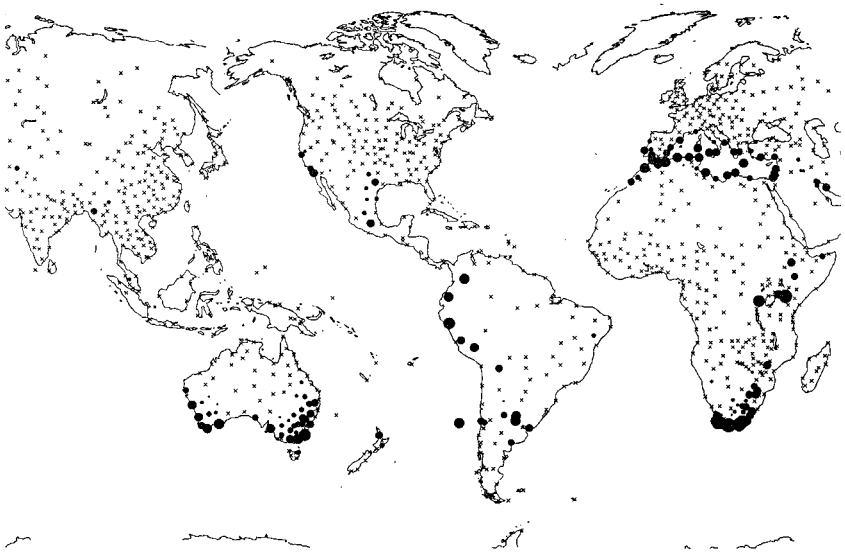

**Figure 4. Prediction of world distribution of *E. spinosa* by CLIMEX.**

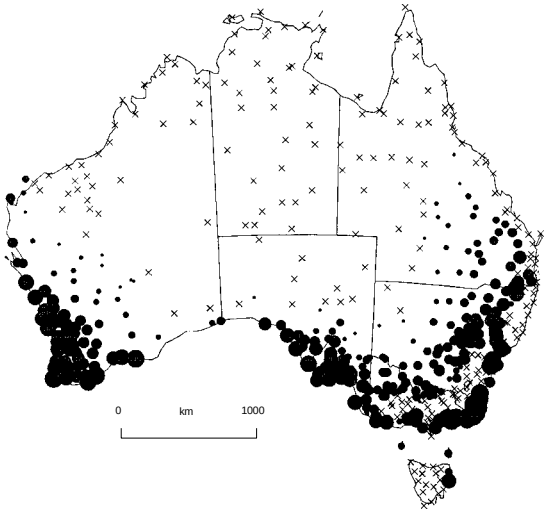


**Figure 5. Prediction of Australian distribution of *E. spinosa* by CLIMEX.**

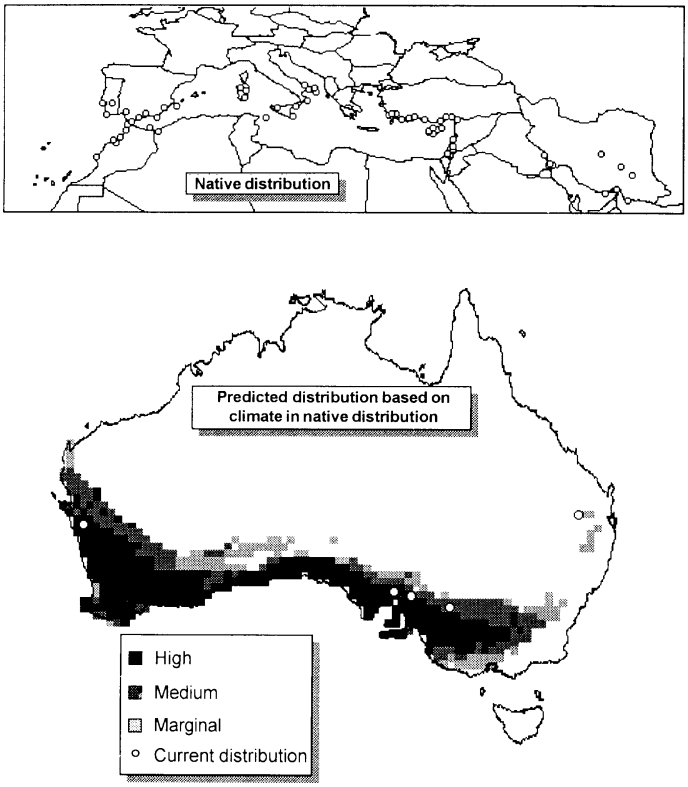


**Figure 6. Prediction of Australian distribution of *E. spinosa* by Climate System. Locations within the native distribution in South Africa (shown) and additional naturalized locations outside of Australia were used to generate the prediction.**

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