Something's bugging butterfly bush in Tasmania

Darren J. Kriticos[1] and Karina J.B. Potter[2]
[1] Ensis, Private Bag 3020, Rotorua, New Zealand
[2] Ensis, Private Bag 12, Hobart, Tasmania 7001 Australia

Summary *Buddleja davidii*, (Franch. (Buddlejaceae), butterfly bush or buddleia) is a native of central China that has become a notorious weed in many temperate and Mediterranean regions. In Tasmania, Australia, *B. davidii* has only been recorded as an incidental naturalised plant, restricted mainly to gardens. The performance of *B. davidii* in New Zealand (NZ) under similar climates to Tasmania indicates that it has the potential to become a major pest in Tasmanian forests. Despite the paucity of natural enemies in Tasmania, it has not yet displayed the expected weedy characteristics there. The reasons for this lack of vigour in Tasmania are clearly non-climatic and could include a lack of suitable pollinators or a maladapted genotype. Depending upon the cause of the present behaviour, different management responses may be appropriate. If the Tasmanian population is genetically benign, then the most appropriate response may be to ignore current plantings and focus upon preventing the introduction of other genotypes into Tasmania. Alternatively, it may be better to eradicate *B. davidii* in Tasmania whilst the option remains viable and prevent further introductions that could include more invasive genotypes.

Keywords Buddleia, *Buddleja davidii*, CLIMEX, climate modelling.

INTRODUCTION

Buddleja davidii, native to central China, is a fast-growing perennial shrub with mauve to purple flowers arranged in dense panicles that are very attractive to butterflies. Initially introduced as an ornamental garden plant, this species is a recognised invasive in many temperate, Mediterranean and subtropical regions of the world where it infests hedgerows, roadsides, landslips, railway tracks, forests, riverbanks and disturbed areas (Blood 2001, Carr *et al*. 1992, Csurhes and Edwards 1998). In Europe, it has been listed as the highest priority weed species for biological control (Sheppard *et al.* 2006).

In NZ, *B. davidii* is subject to Pest Plant Management Strategies in several regions, primarily because it reduces growth and increases mortality of seedlings in plantation forests (e.g. Richardson *et al*. 1999). It also competes with native species (particularly herbs and sub-shrubs), impacting on natural succession (Smale 1990). In NZ, it is commonly controlled using herbicides and is also targeted by the biocontrol agent, *Cleopus japonicus* Wingelmüller (Coleoptera: Curculionidae).

In Australia, *B. davidii* has been recorded as a serious weed in New South Wales and Victoria, but it has only been noted as an incidental naturalised plant in Tasmania, where it is restricted mainly to gardens. Riparian communities support infestations particularly in association with disturbance (Csurhes and Edwards 1998) and damp sclerophyll forests are particularly vulnerable (Carr *et al*. 1992).

Climate modelling is a tool that can be used to assess the potential performance of a weed in a new environment and can indicate whether the species has already reached its full climatic potential (Kriticos and Randall 2001). As *B. davidii* is widespread and a serious environmental and forestry weed in regions of NZ that are climatically similar to parts of southern Australia, this paper examines the potential distribution of the weed in Australia, with particular attention to Tasmania. Possible reasons for the currently observed lack of vigour of *B. davidii* in Tasmania and their impacts on policy responses to this weed for the state are discussed.

MATERIALS AND METHODS

The CLIMEX modelling package (Sutherst *et al.* 2004) was used to model the potential distribution and relative abundance of *B. davidii* using both native Chinese and exotic European distributions of the plant. The native distribution provides an estimation of the realised niche of *B. davidii* in the presence of its natural enemies and under competition from other species. The exotic distribution provides a guide to the fundamental niche of the species. That is, the distribution and abundance a species may achieve under conditions where it is released from the effects of biotic restrictions such as natural enemies.

Native and world-wide distribution The Chinese and world-wide distributions of *B. davidii* were determined from literature reviews (Blood 2001, Houghton 1984, Kay 1991, Kay and Smale 1990, Leeuwenberg 1979, Smith 1991, Wagner *et al.* 1990, Weber 2003, Zhou *et al*. 1993) and a survey of locality data held by various institutions. In most cases, data was provided

in the form of locality names, rather than geographic co-ordinates. World gazetteers were used to derive estimates of coordinates for localities. It should also be noted that Japan was listed as part of the native distribution of *B. davidii* by a number of authors, but no point source data was located (Blood 2001, Houghton 1984, Leeuwenberg 1979).

CLIMEX The CLIMEX Compare Locations model (Sutherst and Maywald 2004) uses climate databases to infer the responses of a taxon to climate. Growth and stress indices are calculated weekly and combined into an overall annual index of climate suitability, the Ecoclimatic Index (EI). The EI provides an indication of the relative ability of a population to grow during favourable conditions and survive stressful conditions. The EI values theoretically range from 0 (unsuitable) to 100 where conditions are optimal throughout the entire year. In practice, EI values above 60 are rare.

Fitting parameters in the native range The CLIMEX parameters were fitted to the known Chinese distribution of *B. davidii* using the standard manual, iterative method (Table 1). A 0.5 degree climate dataset (New *et al*. 1999) was used for most of the parameter-fitting before fine-tuning the parameters using a finer-scale 10' climate dataset (New *et al.* 2002).

Extending the model to the exotic range For the model to allow *B. davidii* to persist in Switzerland and Scotland it was necessary to reduce PDD the threshold annual heat sum to 1020 degree days. It was also necessary to reduce the cold stress accumulation rate to −0.0003 in order to allow persistence in the slightly warmer northern parts of Austria.

To model persistence at Haast on the west coast of the South Island of NZ, it was necessary to increase the wet stress threshold (SMWS) and the maximum soil moisture for growth (SM3) to 1.95 for the 10' climate dataset and 2.0 with the 0.5 degree dataset.

The model was verified by examining the projected potential distribution of *B. davidii* in Asia using the extended model, and the distribution of *B. davidii* in the Americas and Africa was used as a means of validating the model. The final validated model was used to project the potential distribution of *B. davidii* in Australia.

Match climates The match climates module in CLIMEX was used to help confirm the threat *B. davidii* poses to Tasmania. The climates at selected locations in NZ that are known to be highly suitable for *B. davidii* were matched with all points in Tasmania.

RESULTS

In Australia, *B. davidii* is projected to be able to occupy large areas throughout the Mediterranean, temperate and subtropical climate zones including all locations where it has been reported. The climate over most of Tasmania appears highly suitable for *B. davidii* (Figure 1). There is also a close degree of match between selected locations in NZ, where *B. davidii* is known to be particularly weedy, and much of Tasmania (Figure 2).

DISCUSSION

The high degree of climatic suitability of Tasmania for *B. davidii* (Figure 1) and the close climatic similarity of many NZ locations to much of Tasmania is at odds with the fact that this species is only found incidentally in a naturalised condition in Tasmania. We discovered no evidence that it is thriving in the periodically disturbed plantation forest habitat that is

Table 1. CLIMEX parameters for *B. davidii* using the 10' climate dataset.

Parameter	Native Range 10' Climate Dataset[A]
Min. temp. for growth (DV0)	5
Min temp. for optimal growth (DV1)	20
Max. temp. for optimal growth (DV2)	24
Max. temp. for growth (DV3)	27
Min. soil moisture for growth (SM0)	0.2
Min. soil moisture for optimal growth (SM1)	0.5
Max. soil moisture for optimal growth (SM2)	0.9
Max. soil moisture for growth (SM3)	1.5 (1.95)
Cold stress temp. threshold (TTCS)	2
Cold stress accumulation rate (THCS)	−0.00095 (−0.0003)
Heat stress temp. threshold (TTHS)	27
Heat stress accumulation rate (THHS)	0.001
Dry stress soil moisture threshold (SMDS)	0.2
Dry stress accumulation rate (HDS)	−0.005
Wet stress soil moisture threshold (SMWS)	1.5 (1.95)
Wet stress accumulation rate (HWS)	0.006
Hot-wet stress temp. threshold (TTHW)	30
Hot-wet stress soil moisture threshold (MTHW)	1.1
Hot-wet stress accumulation rate (PHW)	0.07
Degree days per generation (PDD)	2450 (1020)

[A] Values in brackets are those that fit the exotic range.

so conducive to its survival and spread in NZ and other parts of the world. The obvious question is why has *B. davidii* not become weedy in Tasmania? Low (2002) describes six reasons that plants do not, or have not yet naturalised, namely they cannot reproduce, they lack a seed dispersal agent, they are outcompeted by other plants, they are suppressed by herbivores and pathogens, the opportunity to naturalise has not yet arisen or the environment is unsuitable.

Buddleja davidii is anemochorous and produces copious seed. It has evolved to disperse effectively to establish in disturbed sites (Smale 1990). Therefore, dispersal limitation is an unlikely explanation for the lack of weediness in Tasmania. Preliminary field observations in Tasmania suggest that intra-specific competition is an unlikely explanation, as there appeared to be ample opportunity for recruitment in the absence of competitors (D. Kriticos and K. Potter pers. obs. 2005). In NZ, *B. davidii* is often found in association with a range of strong competitors including gorse, *Ulex europeaus* L., Scotch broom (*Cytisus scoparius* L. (Link)) and blackberry (*Rubus fruticosus* L. agg.) (D. Kriticos unpublished data).

Reproductive success, both from the standpoint of genetic diversity of Tasmanian *B. davidii* populations and seed production are important foci for future research, as little is known of the levels of seed production, seedling survival or pollinators in Tasmania. However, *B. davidii* is attractive to a wide range of Lepidoptera and pollination is no problem in other locations where it has been reported as a weed.

At this stage, no evidence is available to support the explanation that suppression by herbivores or pathogens is inhibiting naturalisation in Tasmania as field specimens showed no significant evidence of herbivore or pathogen damage.

Climate is the primary limiting factor governing the distribution of plants (Woodward 1987). However, the possibility that the Tasmanian environment is somehow unsuitable for *B. davidii* is challenged by the modelling results presented here.

Finally, it is possible that the opportunity for *B. davidii* to naturalise has not yet arisen and it may only be a matter of time before it becomes invasive. Nonetheless, this catch all 'explanation' for why plants do not, or have not yet naturalised does not indicate the underlying cause of the lack of invasive behaviour. Experimental investigation of the cause of this aberrant behaviour could lead to an insight into a means to control *B. davidii* in Tasmania and elsewhere. In the meantime, in Tasmania we should heed the general advice of Low (2002) and restrict further imports of *B. davidii*, limit its further spread and restrict the importation of new pollinators. The last option has the added

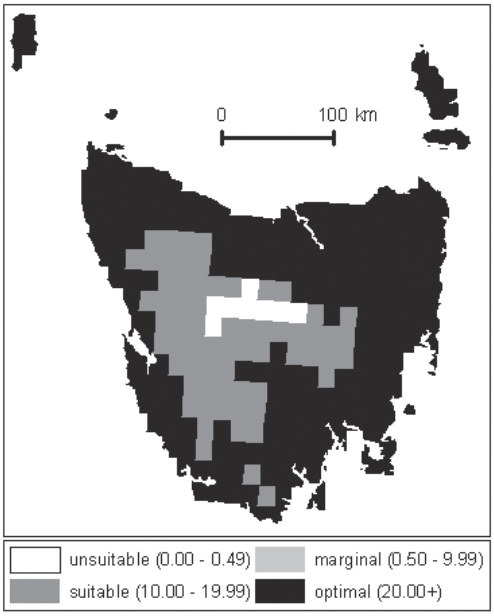

Figure 1. Climate suitability for *Buddleja davidii* in Tasmania modelled using CLIMEX with the 10' dataset.

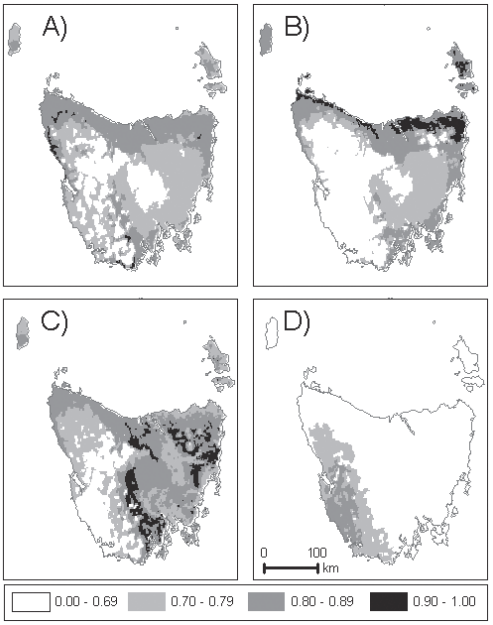

Figure 2. CLIMEX Climate similarities between selected NZ locations where *B. davidii* is known to be problematic and Tasmania. A) Rotorua, B) Gisbourne, C) Kaikoura, and D) Hokitika. Source meteorological data: 0.025 degree dataset for Australia generated using Esoclim (Houlder 2004).

advantage of potentially limiting the rate at which other presently benign exotic plants become weedy.

ACKNOWLEDGMENTS

We thank Nod Kay, Mick Crawley, Susan Ebeling, Susan Timmins, Kate Blood, Chris Dewhurst, Echehart Jager, John Hosking and Sarah Brunel for their assistance with the location of *B. davidii* distribution records. We would also like to acknowledge the efforts of Agathe Leriche-Guichard in producing the figures and valuable comments on the manuscript by Tania Yonow.

REFERENCES

Blood, K. (2001). 'Environmental weeds: a field guide for SE Australia'. (C.H. Jerram & Associates, Melbourne and the CRC for Weed Management Systems, Adelaide).

Carr, G.W., Yugovic, J.V. and Robinson, K.E. (1992). 'Environmental weed invasions in Victoria'. (Department of Conservation and Environment, Melbourne).

Csurhes, S. and Edwards, R. (1998). 'Potential environmental weeds in Australia: candidate species for preventative control'. (Biodiversity Group, Environment Australia, Canberra).

Houghton, P.J. (1984). Ethnopharmacology of some *Buddleja* species. *Journal of Ethnopharmacology* 11, 293-308.

Houlder, D. (2004). ANUCLIM user's guide, version 5.1 [Web Page]. Located at: http://cres.anu.edu.au/outputs/anuclim/doc/Contents.htm. Accessed March 2005.

Kay, M. (1991). The *Buddleja* biocontrol programme. Unpublished internal progress report. (Forest Research, Rotorua, New Zealand).

Kay, M. and Smale, M.C. (1990). The potential for biological control of *Buddleja davidii* Franchet in New Zealand. *In* 'Alternatives to the chemical control of weeds', eds C. Bassett, L.J. Whitehouse and J.A. Zabkiewicz, pp. 29-33. (Ministry of Forestry, Rotorua, New Zealand).

Kriticos, D.J. and Randall, R.P. (2001). A comparison of systems to analyse potential weed distributions. *In* 'Weed risk assessment', eds R.H. Groves, F.D. Panetta and J.G. Virtue, pp. 61-79. (CSIRO Publishing, Melbourne, Australia).

Leeuwenberg, A.J.M. (1979). 'The Loganiaceae of Africa XVIII, *Buddleja* L. II – revision of the African and Asiatic species', eds H. Veenman and B.V. Zonen. (Mededelingen Landbouwhogeschool, Wageningen, The Netherlands).

Low, T. (2002). Why are there so few weeds? Proceedings of the 13th Australian Weeds Conference, eds H. Spafford Jacob, J. Dodd and J.H. Moore, pp. 1-6. (Plant Protection Society of Western Australia, Perth).

New, M., Hulme, M. and Jones, P. (1999). Representing twentieth-century space-time climate variability. Part I: Development of a 1961–90 mean monthly terrestrial climatology. *Journal of Climate* 12**,** 829-56.

New, M., Lister, D., Hulme, M. and Makin, I. (2002). A high resolution data set of surface climate over global land areas. *Climate Research* 21, 1-25.

Richardson, B., Kimberley, M.O., Ray, J.W. and Coker, G.W. (1999). Indices of interspecific plant competition for *Pinus radiata* in the central North Island of New Zealand. *Canadian Journal of Forest Research* 29, 898-905.

Sheppard, A.W., Shaw, R.H. and Sforza, R. (2006). Top 20 environmental weeds for classical biological control in Europe: a review of opportunities, regulations and other barriers to adoption. *Weed Research* 46**,** 93-117.

Smale, M.C. (1990). Ecological role of buddleia (*Buddleja davidii*) in streambeds in Te Urewera National Park. *New Zealand Journal of Ecology* 14, 1-6.

Smith, A.C. (1991). Flora Vitiensis nova: a new flora of Fiji. Lawai, Kauai, Hawaii. *National Tropical Botanical Gardens* 5, 74.

Sutherst, R.W., Maywald, G.F., Bottomley, W. and Bourne, A. (2004). 'CLIMEX v. 2, CD and user's guide'. (Hearne Scientific Software Pty Ltd, Melbourne).

Wagner, W.L., Herbst, D.R. and Sohmer, S.H. (1990). 'Manual of the flowering plants of Hawai'i', revised edition. (University of Hawai'i Press, Honolulu).

Weber, E. (2003). 'Invasive plant species of the world: a reference guide to environmental weeds'. (CABI Publishing, Wallingford, UK).

Woodward, I.F. (1987). 'Climate and plant distribution'. (Cambridge University Press, Cambridge, UK).

Zhang, X., Xi, Y., Zhou, W. and Kay, N. (1993) *Cleopus japonicus*, a potential biocontrol agent for *Buddleja davidii* in New Zealand. *New Zealand Journal of Forestry Science* 23, 78-83.