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Invasion status and risk assessment for *Salvia tiliifolia*, a recently recognised introduction to China

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Summary

This study corrected the misidentification of an alien species, *Salvia tiliifolia*, which had been incorrectly identified as *S. dugesii* (a synonym of *S. melissodora*) in China. The distribution of *S. tiliifolia* in China was surveyed and it was inferred that it was probably introduced into Kunming, Yunnan in the 1990s and then spread to adjacent counties of Yunnan and south-western Sichuan Province. The Australian weed risk assessment (WRA) was used to evaluate its invasive status. To determine the validity of Australian WRA in China, another 25 exotics representing casual alien plants, naturalised plants and invasive plants were tested. The Australian WRA was validated as a legitimate approach in China. *Salvia tiliifolia* scored 14, falling into the category of invasive plants. While the distribution of *S. tiliifolia* is currently restricted to Yunnan and a small part of Sichuan and the species has not displayed an adverse impact on local environments yet, the WRA results indicated that the species was a high risk plant. It was recommended that local land managers should monitor this species and take measures to stop its continuing expansion or eradicate it if possible.

Keywords: Australian WRA, exotics, invasive plants, risk assessment, *Salvia dugesii*, lindenleaf sage, Tarahumara chia.

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Introduction

Every year, thousands of alien species are accidentally or intentionally introduced into new ranges worldwide (Maillet & Lopez-Garcia, 2000). A few of them start to proliferate, spread and ultimately become invasive plants. With its large size and geographic diversity, China has a wide range of habitats and environmental conditions, which make it especially prone to the establishment of alien species (Xie *et al.*, 2001). To date, at least 600 exotics have naturalised in China, but the exact number of invasive species has not been determined (Li & Xie, 2002).

Invasive species have caused serious ecological and economic impacts in recipient areas throughout the world. In the United States, invasive plants, following habitat destruction, are regarded as the second-most critical threat to conservation of biodiversity (Wilcove *et al.*, 1998) and cause $34 billion in economic losses annually (Pimentel *et al.*, 2005). In China, invasive alien species cause economic losses of $14.45 billion annually (Xu *et al.*, 2006). Additionally, invasive exotics have caused adverse impact on local biological

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diversity. For example, the vigorous growth of *Eichhornia crassipes* (Mart.) Solms (water hyacinth) in Dianchi Lake located in Kunming, Yunnan, led to extinction of 13 native hydrophytes (Wu, 1993).

Early management of new high risk invaders, including efforts to keep out introduced species, early detection and eradication or controlling invaders at an acceptable level, can reduce negative impacts on local ecology, economy and human health (Simberloff, 2003; Vander Zanden *et al*., 2010). Evaluating the potential invasiveness for intentional introduction of plants could prevent alien plants from entering new ranges. In situations where prevention fails, early detection followed by a coordinated eradication programme should be considered to contain or eliminate invasive populations before they expand. The cost of detection and eradication of a small number of colonists is trivial, compared with dealing with the problems after populations spread (Vander Zanden *et al*., 2010). Ignorance of effective management approaches during the early phases of alien invasive plants often leads to establishment and infestation of the new invaders (Simberloff, 2003; Conn *et al*., 2011).

Risk assessment schemes have been developed to identify potential invasive species. Rapid development of computing facilities and the accumulated knowledge on the traits of invaders make it possible to develop risk assessment schemes for predicting invasiveness of exotics in recipient regions (Daehler & Carino, 2000; Gassó *et al*., 2010). Previous risk assessment systems for non-native plants in China have concentrated on challenges of predicting invasiveness, rather than how to identify potential invasive plants (Jiang *et al*., 1994; Xu *et al*., 2008). The Australian weed risk assessment (WRA) scheme (Pheloung *et al*., 1999), developed for detecting plant invaders, has been in regulatory use in Australia and New Zealand for over a decade and has been shown to be cost-effective in Australia (Keller *et al*., 2007).The system has successfully been implemented across islands and continents in tropical and temperate climates (Daehler *et al*., 2004; Kato *et al*., 2006; Křivánek & Pyšek, 2006; Gordon *et al*., 2008b; Nishida *et al*., 2009; Crosti *et al*., 2010; Gassó *et al*., 2010; McClay *et al*., 2010), and the assessment results derived from different geographies are similar; on average, over 90% invaders and 70% non-invaders could be recognised through the WRA (Gordon *et al*., 2008a).

Salvia tiliifolia Vahl (lindenleaf sage), native to Central America, is an annual herb that grows up to 1 m tall. It is characterised by broadly ovate leaves, recessed veins and regularly crenate margins, bearing a strong resemblance to those of *Tilia* spp. First described by Vahl in 1794, *S. tiliifolia* as a weed has spread to Mexico, the United States, Ethiopia, South Africa and Australia (Gentry & Standley, 1973; Demissew, 1996; Jäger & Van Staden, 2000). The species arrived in China recently, but field investigations of its occurrence in the region are lacking, as is an assessment for its invasiveness in China. Additionally, Xu *et al*. (2004, 2011) isolated 7 neo-clerodane diterpenoids from an alien sage in China identified as *Salvia dugesii* Fernald and found that tilifodiolide, the major constituent of *S. dugesii,* had been previously isolated from *S. tiliifolia*. We suspected that the '*S. dugesii'* collected in China was in reality *S. tiliifolia*. The aims of the present study were: (i) to survey the current distribution of *S. tiliifolia* in China and (ii) to confirm validity of the Australian WRA system in China and use it to predict invasive status of *S. tiliifolia*.

Materials and methods

Investigation of the distribution of Salvia tiliifolia *in China*

Field investigations for *S. tiliifolia* were conducted in all 16 municipalities/autonomous prefectures of Yunnan, west of Guizhou, south-east of Tibet and west of Sichuan Province from 2010 to 2012. Four to five representative towns with lower forest coverage and more farmland were chosen to be searched in a target county. For specific towns, we searched *S. tiliifolia* via car windows along the main road (many towns of south-west China have only one main roadway), and three to five sites within the road were searched on foot. The county would be recognised as an established site if one population was found. Disturbed areas, such as roadsides, crop fields and forest edges, were the major habitats surveyed.

Application of Australian WRA

The Australian WRA (Pheloung *et al*., 1999) system was chosen for testing the invasiveness of *S. tiliifolia*. The scheme is composed of 49 questions that are divided into three sections: biogeography, undesirable plant attributes and biology/ecology. A minimum of 10 questions, which include at least two in the biogeography section, two in undesirable plant attributes and six in biology/ecology, are needed for a species to be evaluated. The score for each question ranges from −3 to 5, and based on total score the species will be accepted (not a risk – score <1), rejected (high risk on becoming an invasive plant – score >6), or require further evaluation (score 1–6). Daehler *et al*. (2004) developed a secondary screening tool to reduce the proportion of species requiring further assessment with the Australian WRA, and it has proven to be effective (Kato *et al*., 2006; Křivánek & Pyšek, 2006; Gordon *et al*., 2008b). Thus, the secondary screening tool was selected to evaluate all species with WRA scores from one to six.

To reflect the Chinese environment, three of 49 questions from the Australian WRA were modified. Question 2.01 'Species suited to Australian climate' was changed to 'Species suited to Chinese climate'. Question 4.10 was changed from 'Grows on infertile soils' to 'Grows on soil types found in China' because up to fourteen soil types that were considered to be the Chinese soil classification orders were found in China (Cooperative Research Group on Chinese Soil Taxonomy (CRGCST), 1995). The same change in the question was made for predicting plant invasiveness using the Australian WRA in Canada (McClay *et al*., 2010). We also changed question 8.05 'Effective natural enemies present in Australia' to 'Effective natural enemies present in China'.

To confirm whether the WRA is valid in China, another 25 species representing invasive, naturalised and casual alien plants were selected to test (see Table 1). These categories follow Richardson *et al.* (2000).

1 *Casual alien species* are those that do not form reproductive populations outside cultivation and rely on repeated introductions for their persistence.
2 *Naturalised species* reproduce offspring freely but the descendants only disperse around parental plants.
3 *Invasive species* produce reproductive offspring which usually spread distances from parental plants.

Finally, WRA scores tested in other areas for the same species were compared to the scores from China.

Results

Correction of earlier misidentification of the alien Salvia sp

Salvia dugesii, a synonym of *S. melissodora* Lag. (Grape-scented sage), is a perennial shrub (Turner, 2010). However, the species previously identified as *S. dugesii* in China (Xu *et al*., 2004, 2011) is an annual herb, which was probably a misidentification. Through substantial review of relevant references, specimen studies in herbaria of Institute of Botany, Chinese Academy of Sciences (PE), Kunming Institute of Botany, Chinese Academy of Sciences (KUN), and South China Botanical Garden, Chinese Academy of Sciences (IBSC) (abbreviations following Holmgren & Holmgren, 1998) and consulting with Dr. Jay B. Walker (Oklahoma State University, USA), who is an expert on the genus *Salvia*, we confirmed that the specimens identified as *S. dugesii* were *S. tiliifolia*. Therefore, all compounds isolated from the specimens identified as *S. dugesii* (Xu *et al*., 2004, 2011) are actually constituents of *S. tiliifolia*.

Distribution

In total, ten populations of *S. tiliifolia* were discovered in field investigations, of which nine were in Yunnan and one in south-western Sichuan. Of the ten populations, seven were distributed near Kunming, Yunnan, and the other three were hundreds of kilometres away from Kunming (Fig. 1). Within its distribution area, populations were mainly found on roadsides, and a few were dispersed to forest edges and farmlands. The number of individuals of each population varied from hundreds to thousands, and the plants tended to form dense monotypic stands.

Result of WRA test for Salvia tiliifolia

In applying the modified Australian WRA for the 26 test species, we answered an average of 37 questions of 49 (range from 32 to 41) posed by the modified Australian WRA scheme. Total scores and consequent outcomes for each species were summarised in Table 1. All species categorised *a priori* as casual alien plants scored <1, ranging from −2 to −8 (accepted); invasive plants together with *S. tiliifolia,* scored greater than 6, ranging from 8 to 19 (rejected); of the five naturalised plants, only *Plumeria rubra* L. (Red frangipani) scored -3 (accepted), with the others needing further evaluation. We tested the four species scoring between 1 and 6 (needing further evaluation) using a secondary screening tool and found that *Salvia coccinea* Buc'hoz ex Etl. (Texas sage) and *Eucalyptus globulus* Labill. (Tasmanian blue gum) were accepted; *Cosmos bipinnatus* Cav. (Garden cosmos) was rejected; *Acacia dealbata* Link (Silver wattle) required further evaluation. While total scores for the same species probably varied with geographies, the overall conclusions from WRA remained the same for all tested species except *E. globulus* (see Table 1).

Discussion

The Australian WRA recognised all invaders and casual exotics in China. While WRA total scores for the same species may vary with geographies, conclusions for all taxa but *E. globulus* are consistent (see Table 1). *Eucalyptus globulus*, native to Australia, has been introduced to Pacific Islands and other regions

Table 1 Alien species (26) used for invasiveness test with modified Australian weed risk assessment (WRA) or Australian WRA plus a secondary screening tool (Daehler *et al.*, 2004) and the consequent outcomes. Multiple WRA scores for a species represent evaluations of population from different regions

Scientific name	Common name	Family	*A priori* category	Chinese scores	Other's scores	Outcome
Acacia dealbata Link	Silver wattle	Mimosaceae	Naturalised plants	1		Evaluate*
Ageratina adenophora (Spreng.) R.M. King & H. Rob.	Crofton weed	Asteraceae	Invasive plants	19		Reject
Alternanthera philoxeroides (Mart.) Griseb.	Alligator weed	Amaranthaceae	Invasive plants	15		Reject
Amaranthus spinosus L.	Spiny amaranth	Amaranthaceae	Invasive plants	15	18†	Reject
Chenopodium ambrosioides L.	Epazote	Chenopodiaceae	Invasive plants	13		Reject
Conyza canadensis (L.) Cronquist	Canadian horseweed	Asteraceae	Invasive plants	11	12‡,16§	Reject
Cosmos bipinnatus Cav.	Garden cosmos	Asteraceae	Naturalised plants	3		Reject*
Crassocephalum crepidioides (Benth.) S. Moore	Fireweed	Asteraceae	Invasive plants	11		Reject
Eichhornia crassipes (Mart.) Solms	Water hyacinth	Pontederiaceae	Invasive plants	14	18§, 23‡,26†	Reject
Eucalyptus globulus Labill.	Tasmanian blue gum	Myrtaceae	Naturalised plants	1	10†	Accepted*
Euphorbia hirta L.	Garden spurge	Euphorbiaceae	Invasive plants	11		Reject
Galinsoga parviflora Cav.	Gallant soldier	Asteraceae	Invasive plants	12	12¶	Reject
Lantana camara L.	Spanish flag	Verbenaceae	Invasive plants	12	25‡, 32†	Reject
Mimosa pudica L.	Sensitive plant	Mimosaceae	Invasive plants	10	17†, 20‡	Reject
Panicum repens L.	Couch panicum	Poaceae	Invasive plants	12	9†	Reject
Paspalum conjugatum P.J. Bergius	Buffalo grass**	Poaceae	Invasive plants	13		Reject
Petunia hybrida E. Vilm.	Common garden petunia	Solanaceae	Casual alien plants	−8		Accepted
Pistia stratiotes L.	Water lettuce	Araceae	Invasive plants	17	18†, 22§	Reject
Plumeria rubra L.	Red frangipani	Apocynaceae	Naturalised plants	−3	−5†	Accepted
Salvia coccinea Buc'hoz ex Etl.	Texas sage	Lamiaceae	Naturalised plants	2		Accepted*
Salvia farinacea Benth.	Mealycup sage	Lamiaceae	Casual alien plants	−6		Accepted
Salvia leucantha Cav.	Mexican bush sage	Lamiaceae	Casual alien plants	−7		Accepted
Salvia splendens Sellow ex Wied-Neuw.	Scarlet sage	Lamiaceae	Casual alien plants	−5	4†	Accepted
Salvia tiliifolia Vahl	Lindenleaf sage	Lamiaceae	Unknown	14		Reject
Solidago canadensis L.	Canada goldenrod	Asteraceae	Invasive plants	10		Reject
Viola tricolor L.	Heartsease	Violaceae	Casual alien plants	−2		Accepted

*Outcome determined after use of the secondary screening tool (Daehler *et al.*, 2004).
†Ref. Pacific Islands Ecosystems at Risk (website: http://www.hear.org/pier/) –accepted *Salvia splendens* using the secondary screening tool.
‡Gassó *et al.* (2010) – Mediterranean region.
§Nishida *et al.* (2009) – Japan.
¶Crosti *et al.* (2010) – Mediterranean region of Central Italy.
**see Brako, L., A.Y. Rossman & D.F. Farr. 1995. *Sci. Comm. Names* 1–294.

(China, New Zealand, Singapore and west coast of United States). The species was reported as invasive in Chile, Hawaiian Islands, New Zealand and west coast of United States. However, it was only tested using the Australian WRA in the Hawaiian Islands, where it scored 10 and therefore was regarded as high risk plant (PIER, 2012). However, *E. globulus* scored 1 with the modified WRA and was accepted in China after use of the secondary screening tool, classifying it as non-invasive in China. Overall, the Australian WRA effectively evaluated alien plants in China.

Salvia tiliifolia scored 14 with the Australian WRA scheme and therefore could be regarded as a high risk plant. The species is characterised as an annual herb,

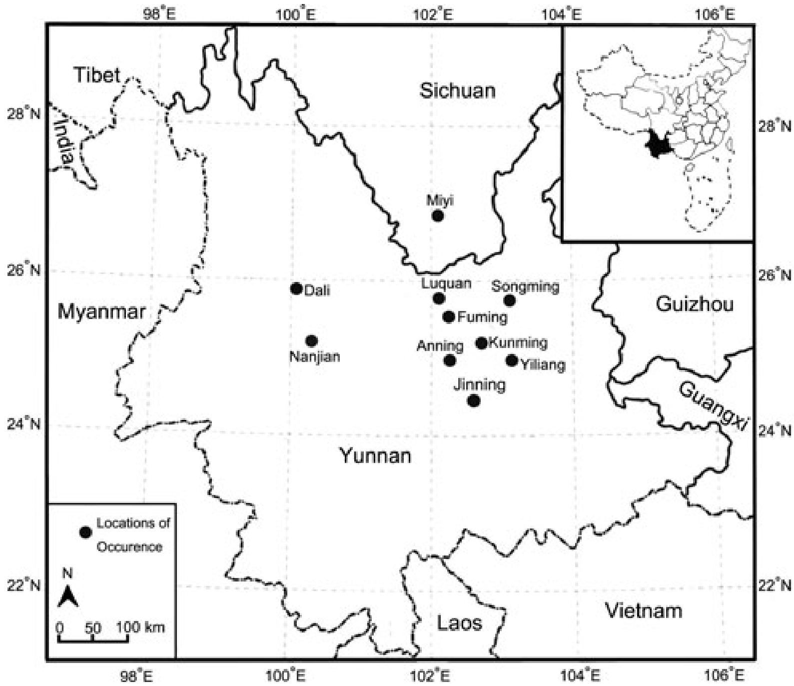

Fig. 1 Current distribution of *Salvia tiliifolia* in China.

prolific seed producer and unpalatable to animals. These characteristics, together with its invasion history in other regions, increase the likelihood that the species is potentially invasive (Williamson & Fitter, 1996; Maillet & Lopez-Garcia, 2000). Its foothold in Ethiopia originated from its presence in grain in a humanitarian aid programme following prolonged droughts, after which the species spread rapidly and was finally uncontrollable (Demissew, 1996). As Perrins *et al.* (1992) states, 'a minor weed today may become a major one when management practices are modified slightly'. *Sorghum halepense* (L.) Pers. (Johnson grass), a serious weed and reservoir for pathogens of crops worldwide, was relatively rare in Austria between 1871 and 1990. However, the species has expanded rapidly in the south and east of Austria and invaded into 41% of grain maize fields and 40% of oil-pumpkin fields since 1990 (Follak & Essl, 2013). Likewise, many invasive plants in China were not noticed until they caused serious adverse impacts, at which point eradication proved difficult. For example, *Ageratina adenophora* (Spreng.) R.M. King & H. Rob. (Crofton weed), a member of Asteraceae native to Mexico, was discovered for the first time in the 1940s in Yunnan Province. This species might have been introduced into China from Myanmar (Liu *et al.*, 1985). Twenty years later, *A. adenophora* started to spread rapidly within the middle and north subtropical zone including Yunnan, Guangxi, Guizhou and Sichuan, with an expansion rate of 20 km per year, and has become one of the most invasive alien species in China (Xie *et al.*, 2001). Not until the early 1980s did local governments and land managers take measures to prevent its expansion. Subsequent attempts to eradicate the species, including biological and chemical controls, have been in vain (He & Liang, 1988). Compared with such significant invaders as *A. adenophora* and *Eichhornia crassipes, S. tiliifolia* has thus far failed to get the attention of Chinese researchers and regulatory authorities, due to its current narrow distribution and relatively benign impacts on local environments. However, its vigorous growth and rapid spread in China should be a concern.

The earliest documented occurrence of *S. tiliifolia* in China was that of Xu *et al.* (2004), who reported it as *S. dugesii*. In combination with earlier individual field investigations, we infer that the species might have been introduced into China in the 1990s. Furthermore, the nature of its introduction into China may differ from that into Ethiopia (Demissew, 1996), because the majority of populations were first observed in Kunming, Yunnan, where there is neither a humanitarian aid area nor a grain production base. The introduction of *S. tiliifolia* to China likely accompanied the introduction of other horticultural species, because congeneric species from Central America, such as *S. splendens* Sellow ex Wied-Neuw. (Scarlet sage) and *S. coccinea*, have been introduced into Kunming in the past few decades (Li & Hedge, 1994). Based on its current distribution (Fig. 1), we inferred that *S. tiliifolia* was introduced and established in Kunming, Yunnan, then spread to neighbouring regions, as far away as south-west Sichuan.

Although its distribution is restricted to Yunnan and a small part of Sichuan and the species has not yet caused an adverse impact on local environments, the assessment outcome from the Australian WRA indicated a high likelihood of invasiveness. As early management of potential invaders can reduce their adverse impacts on economy and ecology, we suggest that local environmental authorities and land managers pay more attention to this species and take some measures to stop its continuing expansion, or even to eradicate it. Due to lack of effective herbicides and natural enemies available locally for this species, hand-removal may be the most effective way to eliminate it.

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References

Conn J, Werdin-Pfisterer N & Beattie K (2011) Development of the Alaska agricultural weed flora 1981–2004: a case for prevention. *Weed Research* **51**, 63–70.

Cooperative Research Group on Chinese Soil Taxonomy (CRGCST) (1995) Chinese Soil Taxonomy (Revised Proposal). Agricultural Science and Technology of China Press, Beijing, China.

Crosti R, Cascone C & Cipollaro S (2010) Use of a weed risk assessment for the Mediterranean region of Central Italy to prevent loss of functionality and biodiversity in agro-ecosystems. *Biological Invasions* **12**, 1607–1616.

Daehler CC & Carino DA (2000) Predicting invasive plants: prospects for a general screening system based on current regional models. *Biological Invasions* **2**, 93–102.

Daehler CC, Denslow JS, Ansari S & Kuo HC (2004) A risk-assessment system for screening out invasive pest plants from Hawaii and other Pacific Islands. *Conservation Biology* **18**, 360–368.

Demissew S (1996) A Central American weedy *Salvia* in Ethiopia. *Lamiales Newsletters* **4**, 3–4.

Follak S & Essl F (2013) Spread dynamics and agricultural impact of *Sorghum halepense*, an emerging invasive species in Central Europe. *Weed Research* **53**, 53–60.

Gassó N, Basnou C & Vila M (2010) Predicting plant invaders in the Mediterranean through a weed risk assessment system. *Biological Invasions* **12**, 463–476.

Gentry JL & Standley PC (1973) *Salvia*. In: Flora of Guatemala (eds PC Standley, JA Steyermark & LO Williams) *Fieldiana* **24**, 273–301. Field Museum of Natural History, Chicago, IL, USA.

Gordon DR, Onderdonk DA, Fox AM & Stocker RK (2008a) Consistent accuracy of the Australian weed risk assessment system across varied geographies. *Diversity and Distributions* **14**, 234–242.

Gordon DR, Onderdonk DA, Fox AM, Stocker RK & Gantz C (2008b) Predicting invasive plants in Florida using the Australian weed risk assessment. *Invasive Plant Science and Management* **1**, 178–195.

He DY & Liang JS (1988) Advances in the control research of *Eupatorium adenophorum*. *Advances in Ecology* **5**, 163–168.

Holmgren PK & Holmgren NH (1998) Index Herbariorum: A Global Directory of Public Herbaria and Associated Staff. New York Botanical Garden, New York, NY, USA.

Jäger AK & Van Staden J (2000) *Salvia* in Southern Africa. In: Sage: The Genus *Salvia* (ed SE Kintzios), 47–52. Harwood Academic Publishers, Amsterdam, the Netherlands.

Jiang Q, Liang YB, Wang NY & Yao WG (1994) Preliminary construction of risk assessment index system for pest species. *Plant Quarantine* **6**, 331–334.

Kato H, Hata K, Yamamoto H & Yoshioka T (2006) Effectiveness of the weed risk assessment system for the Bonin Islands. In: Assessment and Control of Biological Invasion Risk (eds F Koike, MN Clout, M Kawamichi, M De Poorter & K Iwatsuki), 65–72. Shoukadoh Book Sellers, Kyoto, Japan & IUCN, Gland, Switzerland.

Keller RP, Lodge DM & Finnoff DC (2007) Risk assessment for invasive species produces net bioeconomic benefits. *Proceedings of the National Academy of Sciences of the United States of America* **104**, 203–207.

Křivánek M & Pyšek P (2006) Predicting invasions by woody species in a temperate zone: a test of three risk assessment schemes in the Czech Republic (Central Europe). *Diversity and Distributions* **12**, 319–327.

Li XW & Hedge IC (1994) *Salvia*. In: Flora of China, Vol. **17** (eds ZY Wu & PH Raven), 196–223. Science Press, Beijing, China & Missouri Botanical Garden Press, St. Louis, USA.

Li ZY & Xie Y (2002) Invasive Alien Species in China. China Forestry Publishing House, Beijing, China.

Liu LH, Xie SC & Zhang JH (1985) Studies on the distribution, harmfulness and control of *Eupatorium adenophorum* Spreng. *Acta Ecologica Sinica* **5**, 1–6.

Maillet J & Lopez-Garcia C (2000) What criteria are relevant for predicting the invasive capacity of a new agricultural weed? The case of invasive American species in France. *Weed Research* **40**, 11–26.

McClay A, Sissons A, Wilson C & Davis S (2010) Evaluation of the Australian weed risk assessment system for the prediction of plant invasiveness in Canada. *Biological Invasions* **12**, 4085–4098.

Nishida T, Yamashita N, Asai M *et al.* (2009) Developing a pre-entry weed risk assessment system for use in Japan. *Biological Invasions* **11**, 1319–1333.

Perrins J, Williamson M & Fitter A (1992) Do annual weeds have predictable characters? *Acta Oecologica* **13**, 517–533.

Pheloung P, Williams P & Halloy S (1999) A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management* **57**, 239–251.

PIER (2012) Pacific Island Ecosystems at Risk. Plant threats to Pacific ecosystems. Available at: http://www.hear.org/pier/ (last accessed 9 May 2013)

Pimentel D, Zuniga R & Morrison D (2005) Update on the environmental and economic costs associated with alien invasive species in the United States. *Ecological Economics* **52**, 273–88.

Richardson DM, Pysek P, Rejmanek M *et al*. (2000) Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions* **6**, 93–107.

Simberloff D (2003) How much information on population biology is needed to manage introduced species? *Conservation Biology* **17**, 83–92.

Turner B (2010) Recension of the Mexican species of *Salvia* (Lamiacae), Sect. Peninsularis. *Phytologia* **92**, 20–26.

Vander Zanden MJ, Hansen GJA, Higgins SN & Kornis MS (2010) A pound of prevention, plus a pound of cure: early detection and eradication of invasive species in the Laurentian Great Lakes. *Journal of Great Lakes Research* **36**, 199–205.

Wilcove DS, Rothstein D, Dubow J, Phillips A & Losos E (1998) Quantifying threats to imperiled species in the United States. *BioScience* **48**, 607–615.

Williamson MH & Fitter A (1996) The characters of successful invaders. *Biological Conservation* **78**, 163–170.

Wu K (1993) Initial talk about ecosystemic balance of Dianchi Lake waters. *Communication of the Coordination Net of Domestic Lake* **1**, 47–49.

Xie Y, Li ZY, Gregg WP & Dianmo L (2001) Invasive species in China-an overview. *Biodiversity and Conservation* **10**, 1317–1341.

Xu G, Peng L, Niu X *et al*. (2004) Novel diterpenoids from *Salvia dugesii*. *Helvetica Chimica Acta* **87**, 949–955.

Xu H, Ding H, Li M *et al*. (2006) The distribution and economic losses of alien species invasion to China. *Biological Invasions* **8**, 1495–1500.

Xu H, Sun SQ & Wang XH (2008) Construction of risk assessment index system for alien species in Anhui Province. *Journal of Anhui Agricultural Sciences* **36**, 248–249, 261.

Xu G, Zhao F, Yang XW *et al*. (2011) neo-Clerodane diterpenoids from *Salvia dugesii* and their bioactive studies. *Natural Products and Bioprospecting* **1**, 81–86.