Department of **Agriculture and Fisheries**
Biosecurity Queensland

Invasive plant risk assessment

Giant reed

Arundo donax

Steve Csurhes

First published 2009
Updated 2016

Queensland Government

Front cover: Arundo donax in Brisbane
Photo: Sheldon Navie

Contents

Summary

Arundo donax (giant reed) is a tall perennial grass with an obscure origin in India, tropical Asia or the Mediterranean region. It has been cultivated for thousands of years for a variety of purposes. More recently, it has been promoted as a new source of quick-growing 'biofuel' (often referred to as 'Adx').

A. donax has escaped cultivation and naturalised in numerous countries. It is a serious pest in the United States, Mexico and South Africa. It is particularly problematic in California, where it has formed pure stands over thousands of hectares of riparian habitat. These infestations have reduced natural biodiversity and pose a significant fire risk. In arid parts of the USA, *A. donax* uses substantial amounts of ground-water, taking a resource that could otherwise be used by agriculture, people and wildlife. In the Santa Ana River alone, *A. donax* is estimated to use drinking water valued at $18 million each year.

Based on the evidence collected by this study, it seems reasonable to conclude that *A. donax* has the potential to become a significant weed in certain riparian habitats in Queensland, as it has done elsewhere in the world. Areas most at risk appear to be well-drained soils associated with disturbed riparian (freshwater) habitats in the subtropics.

Currently, populations of *A. donax* in Queensland are small and localised, despite being first planted as early as 1912. Long 'lag times' between introduction and development of significant negative impacts are well documented across a range of invasive species, and as such, the species' population development could simply be a matter of time. Moreover, the development of a serious problem in California may have taken more than 400 years, after it was first imported by Spanish settlers in the early 1500s. Having made this point, there could be other reasons for the apparent failure to develop extensive populations in Queensland. The existence of a single genetic clone of *A. donax* in the USA could be significant as it might be a particularly invasive form of the species. The existence of this specific type in Australia has not yet been determined. Hence, import of clonal material from the USA might 'trigger' more rapid population development in Australia.

Introduction

Identity and taxonomy

Species identity: *Arundo donax* L. (Poaceae)

Common names: Giant reed, bamboo, Danubian reed, Elephant grass, giant Danube reed, Spanish reed (Shepherd et al. 2001); donax cane (GBIF undated); Adx (recent commercial name)

Taxonomy

Arundo is a genus of three species from Asia and the Mediterranean region (*Grass Manual of North America*). The other species are *A. formosana* Hackel (2n = 72), native to Formosa and East Asia, and *A. plinii* Tura (2n = 40), native to the Mediterranean region (Clayton et al. 2006).

A commercial horticultural variety is available: *Arundo donax* var. *versicolor* (Mill.) Stokes (syn. *A. donax* var. *variegata*). This was described in *Miller's Gardening Dictionary* in 1768 (Perdue, 1958). It is a diminutive of typical *A. donax* except for the variegated leaves. There are many synonyms for *A. donax* (Table 1).

Table 1. Names that have been used (correctly or incorrectly) as synonyms with *Arundo donax* L.

Aira bengalensis (Retz.) J.F. Gmel.
Amphidonax bengalensis (Retz.) Nees ex Steud.
Amphidonax bengalensis Roxb. ex Nees.
Amphidonax bifaria (Retz.) Nees ex Steud.
Arundo aegyptiaca hort. ex Vilm.
Arundo bambusifolia Hook. f.
Arundo bengalensis Retz.
Arundo bifaria Retz.
Arundo coleotricha (Hack.) Honda.
Arundo donax var. *angustifolia* Döll.
Arundo donax var. *coleotricha* Hack.
Arundo donax var. *lanceolata* Döll.
Arundo donax var. *procerior* Kunth.
Arundo donax var. *versicolor* (Mill.) Stokes.
Arundo glauca Bubani.
Arundo latifolia Salisb.
Arundo longifolia Salisb. ex Hook. f.
Arundo sativa Lam.
Arundo scriptoria L.
Cynodon donax (L.) Raspail.
Donax arundinaceus P. Beauv.
Donax bengalensis (Retz.) P. Beauv.
Donax bifarius (Retz.) Trin. ex Spreng.
Donax donax (L.) Asch. and Graebn.

Description

A. donax is a perennial grass that grows to 3–6 m in height, but up to 10 m high under ideal conditions (Figure 1). The leaves are 30–100 cm long, 2–7 cm wide and clasp the stem (Figures 2 and 3).

Figure 1. *Arundo donax* on a creek bank at Brookfield, Brisbane (photo: Steve Csurhes).

Figure 2. Leaves of *Arundo donax* (photo: Steve Csurhes).

Figure 3. Stem-clasping leaf base of *Arundo donax* (photo: Steve Csurhes).

A. donax is often confused with common reed (*Phragmites australis*) and bamboo.

Stems are hollow and 2–3 cm in diameter. The 'flowers' (panicles) are upright, feathery and 30–60 cm long (up to 30 cm wide) (Figures 4, 5).

Figure 4. Flowers starting to emerge in late summer on *Arundo donax* (photo: Steve Csurhes).

Figure 5. Mature flower-head of *Arundo donax* (photo: Sheldon Navie).

Spikelets are 10–15 mm, with 2–4 florets. Glumes are as long as the spikelets, thin, brownish or purplish, 3-veined and long-acuminate. Lemmas are 8–12 mm, 3–5-veined, pilose, hairs 4–9 mm, apices bifid, midvein ending in a delicate awn; paleas 3–5 mm, pilose at the base. Anthers are 2–3 mm. Caryopses are 3–4 mm, oblong, light brown. 2n = 24, 100 or 110 (*Grass Manual of North America*).

Ornamental cultivars have been developed for use in gardens; var. *variegata*, Syn. *A. donax* var. *versicolor* (which has leaves with white stripes) (Figure 6) and var. *macrophylla* (with large glaucous leaves).

Figure 6. The variegated ornamental cultivar of *Arundo donax* (photo: Sheldon Navie).

Reproduction and dispersal

Flowering starts in late summer (early April in coastal south-east Queensland).

Seeds are rarely produced. John et al. (2006) examined more than 36 000 florets and found only five ovules that may have been viable. Instead, dispersal is achieved from broken sections of rhizomes and stems, which are readily carried by floodwater. When growing away from the reach of floodwaters, dispersal is often slow, with only a gradual increase in clump size as new stems arise from an expanding rhizome base. Rhizomes can extend up to 1 m deep into the soil (Alden et al. 1998; Mackenzie, 2004). Pieces of either broken stem or rhizome less than 5 cm long and containing a single node can produce a new plant under a variety of conditions (Boose and Holt, 1999).

On the rare occasions that seeds are produced, they are dispersed by the wind (Felger, (1990). This study was unable to find information on seed longevity.

There is molecular evidence that naturalised populations of *A. donax* in the USA and France are a single genetic clone (Ahmad et al. 2008), despite multiple introductions being made (Perdue, 1958). This confirms that dispersal is vegetative and suggests that a single genetic clone has been cultivated in multiple regions of the world (Ahmad et al. 2008). However, no studies have been undertaken to determine whether Australian material is the same clone as material in the USA.

Origin and distribution

The exact origin of *A. donax* is obscure, since it has been cultivated (and transported) throughout Asia, southern Europe, North Africa, the Middle East and elsewhere for possibly up to 5000 years (Perdue, 1958). Some references state that *A. donax* is native to tropical Asia and the Mediterranean region. For example, Polunin and Huxley (1987) stated that it is native to the freshwaters of eastern Asia. Others state that it is native to India. A recent report by the USDA (2008) stated that '*A. donax* is native to Europe from the central Atlantic coast of Portugal, inland along the major rivers of the Iberian Peninsula, along the Mediterranean coast from Spain to Greece, including the warmer parts of the Adriatic coast. In North Africa along the Mediterranean, the populations are discontinuous from the Western Sahara, Morocco, Algeria, to the Arabian Peninsula. Remote populations are known from the Sahara in stable oases. Populations in China are not known to be native.'

In addition to its native range, the global distribution of *A. donax* now includes naturalised populations in North and South America, Asia, Australia, New Zealand and numerous islands across the Pacific (Figure 7).

Figure 7. Global distribution of *Arundo donax* (source: GBIF undated).

Status in Australia and Queensland

A. donax is widespread in Australia (Figure 8), probably due to a long history of cultivation for a variety of purposes such as windbreaks and garden ornamentals.

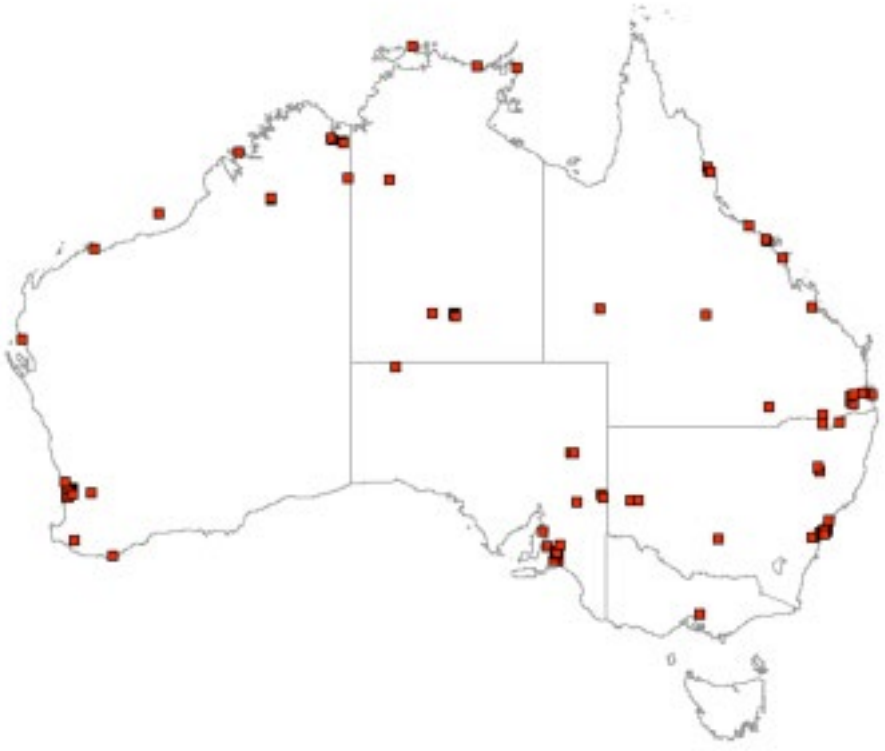

Figure 8. Locations where *Arundo donax* has been collected and recorded by Australian herbaria (source: Australian Virtual Herbarium).

The Queensland Herbarium holds 37 records of *A. donax*, with the earliest specimen collected in 1912 at Malanda on the Atherton Tableland. The frequency of collection and reporting has increased in the past decade (Figure 9), perhaps reflecting either increasing collection effort, or an expanding population of *Arundo donax*.

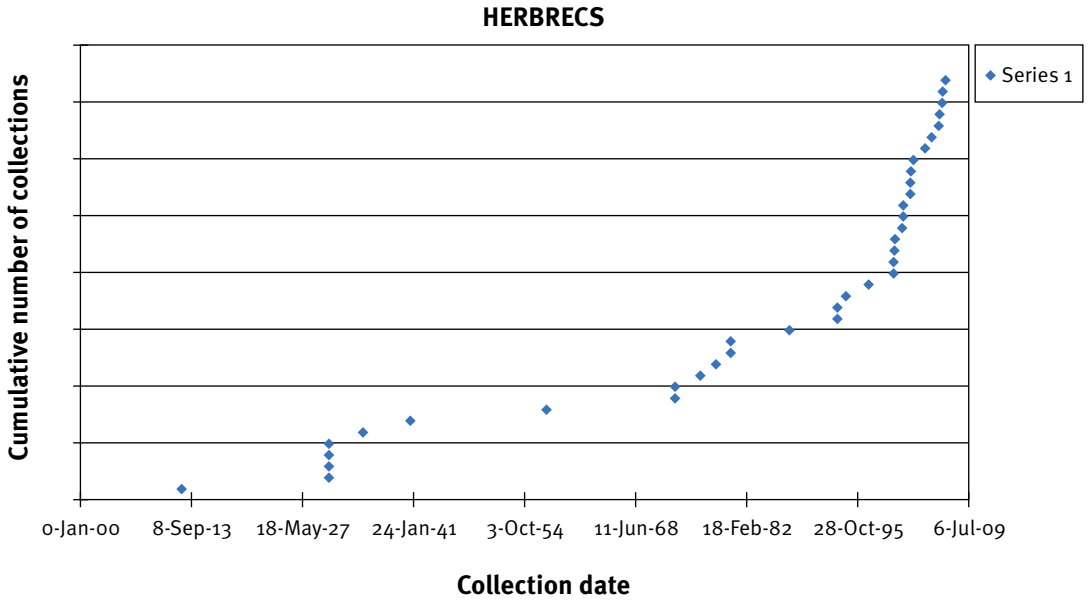

Figure 9. Cumulative total of *Arundo donax* specimens collected by the Queensland Herbarium since 1912.

Preferred habitats

A. donax can tolerate a wide range of climates in areas that receive 300–4000 mm rainfall per annum (DiTomaso, 1998). Globally, it has naturalised in tropical, subtropical and warm temperate areas, including Fiji, New Caledonia, California and the north island of New Zealand. Perdue (1958) stated that it is a 'warm temperate to subtropical species' but 'does not flourish under true tropical conditions'. It suffers serious damage from frosts (Perdue, 1958) and does not survive in areas with prolonged or regular periods of freezing temperatures (DiTomaso and Healy, 2003).

A. donax can grow in infertile and saline soils and responds strongly to fertiliser. It can grow in a variety of soil types, from coarse river sands to heavy clays, but generally prefers well-drained soils above the mean water level in freshwater streams (Perdue, 1958; Singh et al. 1997; Decruyenaere and Holt, 2001). *A. donax* is a hydrophyte and grows best where water tables are near the soil surface (Rezk and Edany, 1979). When growing along the banks of freshwater ditches, creeks and rivers, *A. donax* is generally most abundant and dominant in open sites (full sun) where the original native vegetation has been recently damaged or removed (Figure 10). Recent ecological research by Quinn and Holt (2008) in California found that growth rates for *A. donax* were generally high on sites with bare soil and high moisture levels. While much of California experiences semi-arid conditions, *A. donax* dominates large areas of riparian habitats, where there is sufficient soil moisture. In wetter regions, such as Fiji, *A. donax* persists further away from riparian habitats, including areas described as 'hillsides, open forest and along roadsides, up to about 200 m elevation' (Smith, 1979). Perdue (1958) reported *A. donax* at an altitude of 2438 m in the Himalayas (presumably in a moist site).

Ecologically, *A. donax* can act as an early successional pioneer, since it is well adapted to colonise riparian habitats frequently disturbed by flood events, but also as a late-successional dominant (McWilliams, 2004).

Figure 10. Typical infestation of *Arundo donax* in coastal south-east Queensland growing in a highly disturbed riparian site (photo: Steve Csurhes).

History as a weed elsewhere

A. donax has naturalised in numerous countries. In many places its impact appears to be localised and minor. However, it is considered to be a major problem in Mexico, South Africa and parts of the United States, especially California, Arizona and Texas, and in particular the Santa Ana River basin and Rio Grande basin (USDA 2008, Milton 2004, Van Wilgen et al. 2007). The Global Invasive Species Database lists *A. donax* among the world's 100 worst invasive species (IUCN, undated).

A. donax was originally imported into North America perhaps as early as the 1500s by the Spanish (as a source of fibre) (USDA, 2008). It was planted in California in the late 1700s and early 1800s for erosion control in drainage canals and as wind-breaks (USDA, 2008; Mackenzie, 2004). Today, it dominates 'tens of thousands of acres' of riparian habitat in California (Bell, 1997). Areas that once supported a mix of native plant species are now pure stands of *A. donax*. Within these pure stands, natural biodiversity has been significantly reduced. Herrera and Dudley (2003) recorded only half the diversity and abundance of aerial invertebrates in stands of *A. donax*, compared with native vegetation, with some threatened species of birds relying heavily on invertebrates for food. In addition, extensive stands of *A. donax* serve as a fuel source for wildfires. Areas that rarely experienced wildfire prior to invasion by *A. donax* are now prone to serious fires, resulting in further disruption to ecosystem processes and loss of native plants and animals (Frandsen and Jackson, 1994). Moreover, in some riparian areas, fire has become the primary influence on plant community structure and floristic composition, rather than floods. Such changes to ecosystem function have lead to some authors referring to *A. donax* as a 'transformer species' (e.g. Rieger and Kreager, 1989).

A recent USDA Environmental Assessment (2008) stated that the impact of *A. donax* in riparian habitats includes: loss of biodiversity; stream bank erosion; altered channel morphology; damage to bridges; increased costs for chemical and mechanical control along transportation corridors. Its height and density causes problems for law enforcement activities on the US–Mexico border and also hampers stream navigability (Dudley, 2000).

Stands of *A. donax* can consume up to 2000 litres of water per square meter of plants (Purdue, 1958; Iverson, 1994). Along the Santa Ana River, *A. donax* was estimated to use drinking water to the value of $18 million per annum, enough water to serve 280 000 people (Iverson, 1998). Such prodigious use of water becomes particularly significant in arid areas, where water is critical to the survival of natural ecosystems, agriculture and municipal users (Goolsby et al. 2008). *A. donax* is listed as a noxious plant in Texas (Texas Administrative Code, 2005) and is still spreading elsewhere in the USA. For example, it is becoming a 'persistent non-native species in state parks in central Florida' (Mack, 2008). *A. donax* is listed as a weed on numerous islands in the Pacific, including Hawaii, Fiji and New Caledonia. In Hawaii, it has 'naturalised in coastal areas, often in thickets' (Wagner et al. 1999).

A. donax is an alternative host for beet western yellows virus, sugar cane mosaic virus and maze dwarf mosaic virus (USDA, 2008).

In Australia, *A. donax* has naturalised in almost every state and is formally listed as a 'declared' weed in New South Wales, under the *Noxious Weeds Act 1993*, in 14 local government areas, as outlined in Table 3.

Table 2. Declaration status of *Arundo donax* in New South Wales.

Area	Class	Legal requirements
Blue Mountains, Hunters Hill, Hornsby, Ku-ring-gai, Lane Cove, Manly, Mosman, North Sydney, Parramatta, Pittwater, Ryde, Warringah, Willoughby	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed
Lord Howe Island	3	The plant must be fully and continuously suppressed and destroyed and the plant may not be sold, propagated or knowingly distributed

Uses

A. donax is grown for a variety of purposes.

The sound produced by woodwind instruments, such as the clarinet, is produced by a vibrating cane reed. This reed is typically made from *A. donax* and is preferred by professional clarinetists over plastics and most other wood substitutes (Obataya and Norimoto, 1999; Obataya, 1999). An international reed supplier in South Australia produces professional quality reeds from *A. donax* grown in plantations within that state. There do not appear to be any large-scale commercial growers for the music industry in Queensland, but there might be a small 'backyard' trade.

Other uses include wind-break, erosion control, saline ground reclamation, garden ornamental, paper production, treatment of waste water (removal of nutrients), forage and, more recently, as a potential source of biofuel. For example, in South Australia it has been suggested that *A. donax* could be grown in ponds used to collect saline water, then harvested for biofuel (J. Virtue pers. comm.). Similar ideas are currently being suggested in other parts of Australia. Under ideal conditions, *A. donax* can grow at a rate of 10 cm per day, placing it among the fastest growing plants (Perdue, 1958; Bell, 1997; USDA, 2008). It can produce more than 20 tonnes above-ground dry matter per hectare (Perdue, 1958). Such growth rates have generated much enthusiasm from people keen to produce 'biofuel' and a considerable amount of literature exists on this issue (see Mack 2008 for an overview). However, the utilisation of *A. donax* as a resource is controversial, since it offers both potential benefits and potential costs, in terms of its weed risk. This study assesses the species' weed risk and is not an assessment of the species potential value as a resource.

Pest potential in Queensland

Based on the evidence collected by this study, it seems reasonable to conclude that *A. donax* has the potential to become a significant weed in certain riparian habitats in Queensland. This conclusion is based largely on the fact that *A. donax* is a major weed in the USA, especially riparian habitats in California and Arizona.

Habitats at risk in Queensland appear restricted to riparian zones, namely creek banks, river banks and freshwater wetlands. Such habitats are naturally prone to disturbance by floods and these events could facilitate dispersal of the species' rhizomes and stem fragments. Once established *A. donax* could replace native plant species and facilitate more frequent and intense bushfires, further modifying this habitat type. It is well adapted to survive fire and quickly regenerates from underground rhizomes (Bell, 1997; Scott, 1994).

Climatically, *A. donax* appears suited to large areas of Queensland (Figure 11). Riparian habitats in semi-arid and arid areas of southern Queensland are perhaps most at risk, although this species can tolerate a broad range of conditions. The current distribution of *A. donax* in Australia (Figure 8), which includes a number of arid sites, as well as coastal sites, tends to support this prediction.

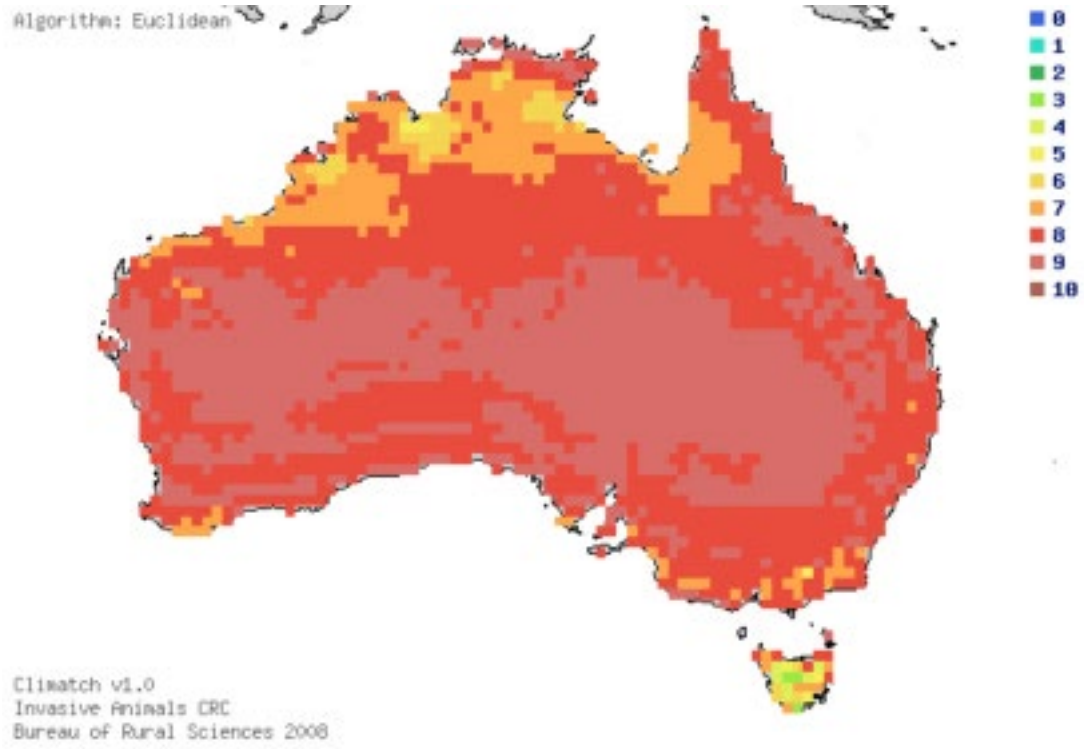

Figure 11. Areas of Australia where climate appears suitable for survival of *Arundo donax* (this model was generated using 'Climatch version 1.0' climate-matching computer program and was based on global distribution data for the species (GBIF undated) together with all Australian collection sites within 20 km of a meteorological station—the model only used temperature parameters and assumed that rainfall is unlikely to be a significant limiting factor to survival in permanent riparian areas). Legend: blue and green = areas where climate is considered unsuitable for this species, yellow and orange = areas where climate is marginally suitable, red and brown = areas where climate is highly suitable (map by Martin Hannan-Jones).

It is relevant to note that *A. donax* has existed in Queensland since at least 1912. Over this time, the species has failed to develop extensive infestations, remaining localised and generally benign. However, long 'lag times' between introduction and development of significant negative impacts are well documented across a range of invasive species, and as such, the development of a significant problem could simply be a matter of time. Naturalised populations of *A. donax* in California developed over a considerable period, possibly since the 1500s. Having made this point, there could be other reasons for the apparent failure to develop extensive populations in Queensland. The existence of a single genetic clone of *A. donax* in the USA could be significant as it might be a particularly invasive form of the species. The existence of this specific type in Australia has not yet been determined. Hence, import of clonal material from the USA could 'trigger' more rapid population development in Australia. Currently, *A. donax* is not (legally) permitted entry (without assessment) under Schedule 5 ('Permitted seeds') of the Quarantine Proclamation 1998.

Control

A. donax is well adapted to survive fire and quickly regenerates from underground rhizomes (Bell, 1997; Scott, 1994).

Information on management of *A. donax* using herbicides is summarised by Bell (1997).

Once established over large areas, such as the rivers of California, control of *A. donax* becomes generally ineffective and expensive (USDA, 2008). Hence, the USDA has sought release of the arundo wasp (*Tetramesa romana*) as a potential biological control agent.

References

Ahmad, R, Liow, PS, Spencer, DF, Jasieniuk, M (2008). Molecular evidence for a single genetic clone of invasive Arundo donax in the United States, *Aquatic Botany* 88: 113–120.

Alden, P, Heath, F, Leventer, A, Keen, R, Zomfler, WB, (eds). (1998). *National Audubon Society Field Guide to California*. Knopf, New York.

Bell, G (1997). Ecology and management of *Arundo donax*, and approaches to riparian habitat restoration in Southern California. In: Brock, JH, Wade, M, Pysek, P, and Green, D (eds): *Plant Invasions: Studies from North America and Europe.* Blackhuys Publishers, Leiden, The Netherlands, pp. 103–113.

Boland, JM (2006). The importance of layering in the rapid spread of *Arundo donax* (Giant reed), *Madroño* 53(4): 303–312.

Boose, AB, and Holt, JS (1999). Environmental effects on asexual reproduction in *Arundo donax*, *Weeds Research* 39: 117–127.

Clayton, WD, Harman, KT and Williamson, H. (2006 onwards). GrassBase—The Online World Grass Flora. www.kew.org/data/grasses-db.html (accessed 13 March 2009).

Decruyenaere, JG and Holt, JS (2001). Seasonality of clonal propagation in giant reed, *Weed Science* 49: 760–767.

DiTomaso, JM (1998). *Biology and ecology of giant reed.* In: Bell, CE (ed). In: Arundo and saltcedar: the deadly duo, Proceedings of a workshop on combating the threat from arundo and saltcedar, 1998, Ontario, Canada. University of California, Cooperative Extension: 1–5.

DiTomaso, JM and Healy, EA (2003). *Aquatic and riparian weeds of the west*, University of California, p. 441.

Felger, RS (1990). Non-native plants of Organ Pipe Cactus National Monument, Arizona. Technical Report Number 31, Tucson, Arizona, University of Arizona, School of Renewable Natural Resources, Cooperative National Park Resources Studies Unit, 93 p.

GBIF (undated). Global Biodiversity Information Facility, www.gbif.org (accessed 12 March 2009).

Herrera, AM and Dudley, TL (2003). Reduction of riparian arthropod abundance and diversity as a consequence of giant reed (*Arundo donax*) invasion, *Biological Invasions* 5: 167–177.

IUCN (undated). Global Invasive Species Database, Invasive Species Specialist Group (ISSG) of the Species Survival Commission of the IUCN-World Conservation Union. www.issg.org/database/species/ecology.asp?si=112&fr=1&sts=&lang=EN (accessed 2 April 2009).

Iverson, ME (1994). The impact of *Arundo donax* on water resources, In: Jackson, NE, Frandsen, S and Douthit, S (eds), *Arundo donax* workshop proceedings (November 1993), pp. 19–25, Ontario, Canada.

Iverson, ME (1998). Effects of *Arundo donax* on water resources, CalEPPC News, p. 10.

Johnson, M, Dudley, T and Burns, C (2006). Seed production in *Arundo donax*? Cal-IPC News Fall 2006, p. 12.

Lewandowski, I, Scurlock, JMO, Lindvall, E. and Christou, M (2003). The Development and current status of perennial rhizomatous grasses as energy crops in the US and Europe, *Biomass and Bioenergy* 25: 335–361.

Mack, RN (2008). Evaluating the credits and debits of a proposed biofuel species: giant reed (*Arundo donax*), *Weed Science* 56: 883–888.

Mackenzie, A (2004). Giant Reed. In: *The Weed Workers' Handbook*. C. Harrington and A. Hayes (eds.) www.cal-ipc.org/file_library/19646.pdf

McWilliams, JD (2004). *Arundo donax*. In: Fire effects information system, (online), US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (producer), www.fs.fed.us/database/feis/

Milton, SJ (2004). Grasses as invasive alien plants in South Africa, *South African Journal of Science* 100: 69-75.

New South Wales Department of Primary Industries (2005). Noxious weed Declarations, www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/noxweed (accessed 12 March 2009).

Obataya, E and Norimoto, M (1999). Acoustic properties of a reed (*Arundo donax* L.) used for the vibrating plate of a clarinet, *Journal of the Acoustical Society of America* 106 (2): 1106–1110.

Obataya, E (1999). Suitability of acetylated woods for clarinet reed, *Journal of Wood Science* 45: 106–112.

Perdue, RE, (1958). *Arundo donax*—Source of musical reeds and industrial cellulose, *Economic Botany* 12: 368–404.

Polunin, O and Huxley, A (1987). Flowers of the Mediterranean, Hogarth Press, London.

Quinn, LD and Holt, JS (2008). Ecological correlates of invasion by *Arundo donax* in three southern California riparian habitats, Biological Invasions 10: 591–601.

Rezk, MR and Edany, TY (1979). Comparative responses of two reed species to water table levels, *Egyptian Journal of Botany* 22: 157–172.

Rieger, JP, Kreager, DA (1989). Giant reed (*Arundo donax*): a climax community of the riparian zone. In: Protection, management, and restoration for the 1990s: *Proceedings of the California Riparian Systems Conference,* September 1988. Davis, California. General Technical Report PSW–110. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station Berkeley, California, pp. 222–225.

Scott, G (1994). Fire threat from *Arundo donax*. pp. 17–18. In: Proceedings of an *Arundo donax* workshop (November 1993), (eds) Jackson, NE, Frandsen, P, Douthit, S (eds.). Ontario, California.

Shepherd, RCH, Richardson, RG and Richardson, FJ (2001). 'Plants of importance to Australia—a checklist', RG and FJ Richardson, Meredith, Victoria.

Singh, C, Kumar, V and Pacholi, RK (1997). Growth performance of *Arundo donax* (giant reed) under difficult site conditions of Doon-Valley for erosion control. Indian Forestry, January 1997: 73–76.

Smith, AC (1979). Flora Vitiensis nova: a new flora of Fiji, National Tropical Botanical Garden, Hawaii.

Starr, F, Starr, K and Loope, L (2003). *Arundo donax* (Giant reed–Poaceae)

Texas Administrative Code (2005). Quarantines and noxious plants, Chapter 19 (May 2006), State of Texas.

USDA (2008). Field Release of the Arundo Wasp, *Tetramesa romana* {Hymenoptera: Eurytomidae}, an Insect for Biological Control of *Arundo donax* {Poaceae}, in the Continental United States Environmental Assessment October 2008. www.regulations.gov/fdmspublic/component/main?main=DocketDetail&d=APHIS-2008-0141 (accessed 13.03.09).

Van Wilgen, BW, Nel, JL and Rouget, M (2007). Invasive alien plants and South African rivers: a proposed approach to the prioritisation of control operations, *Freshwater Biology* 52: 711-723.

Virtue, J. Pers. comm.

Wagner, WL, Herbst, DR and Sohmer, SH (1999). Manual of the flowering plants of Hawaii. Revised edition. Bernice P. Bishop Museum special publication. University of Hawaii Press/ Bishop Museum Press, Honolulu (two volumes).