Review

The biology of Australian weeds 53. *Cylindropuntia rosea* (DC.) Backeb. and *Cylindropuntia tunicata* (Lehm.) F.M.Knuth

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Nomenclature and descriptions

Until relatively recently the polymorphic genus *Opuntia* included many discordant groups with stems ranging from flattened pad-like segments to cylindrical or ovoid ones and variable flowers, fruit and seed. Today it is generally accepted that these groups represent distinct genera and, in addition to *Opuntia*, 14 segregate genera are now recognized, including *Cylindropuntia* and *Austrocylindropuntia*. Some of these genera, such as *Cylindropuntia*, were previously recognized by some authors at subgeneric level within *Opuntia*.

Opuntia and the segregate genera (Anderson 2001) comprise the subfamily Opuntioideae within the Cactaceae, with a unique feature of the presence of glochids in the areoles. Glochids are small detachable barbed bristles, usually aggregated in dense clusters, that cause considerable skin irritation and are difficult to remove.

Pinkava (2004) recognized 35 species of *Cylindropuntia*, eight of which have naturalized in various parts of Australia (Botanic Gardens Trust 2008). Species of *Cylindropuntia* are succulent shrubs, mostly with cylindrical to club-shaped jointed segments and shallow widely spreading roots. Areoles also contain spines with a detachable papery sheath, very obvious in species like *C. rosea* (DC.) Backeb. and *C. tunicata* (Lehm.) F.M.Knuth but more obscure in species such as *Cylindropuntia fulgida* (Engl.) F.M.Knuth var. *mamillata* (Schott ex Engl.) Backeb. Pulp surrounds the seeds in fruit of species (such as *C. tunicata*) that produce seed. *Cylindropuntia* occurs naturally in southern North America, Central America and on Caribbean islands but many species have naturalized in other countries. Another similar genus naturalized in Australia in the subfamily Opuntioideae, *Austrocylindropuntia*, also has cylindrical stem segments but is readily distinguished from *Cylindropuntia* by the absence of the papery sheath on the spine.

Cylindropuntia was recognized as a subgenus by Engelmann in 1856 and raised to generic status by F.M.Knuth in 1935. The name is derived from the Latin *cylindricus* meaning cylinder, probably referring to the shape of the segments, and *opuntia* is apparently from the Greek town Opus where plants were naturalized or cultivated (Telford 1984, Pinkava 2004).

Species

1. *Cylindropuntia rosea* (DC.) Backeb., *Die Cactaceae* 1: 197 (1958).

Synonymy: *Opuntia rosea* DC., *Prodr.* (DC.) 3: 471 (1828). Common name: Hudson pear (Australia).

The specific epithet is derived from the Latin *roseus*, 'reddening' and presumably refers to the rose-coloured or pink flowers. The common name is after a resident of the Lightning Ridge area, Mr Hudson, who first brought the problem to the attention of the then Prickly Pear Destruction Commission.

A branched shrub cactus with a cylindrical trunk, most plants low growing, but some reaching 1.6 m high and to 3 m wide (Figure 1). ***Stem segments*** rope-like, cylindrical, green to grey-green, up to 90 cm long and 4 cm wide (excluding spines). ***Tubercles*** pronounced, elongate, up to 3 cm long and 1 cm wide. ***Areoles*** (small depressions on the tubercle) elliptic, 3–7 mm long, *c.* 3 mm wide, with tan-coloured wool and clusters of yellowish-tan glochids (smaller barbed bristles), 1.5–2.5 mm long. ***Spines*** 4–8 (up to 20 on older stems), white to silvery, up to 4.5 cm long on outer segments. ***Spine sheath*** white, papery, separating during the first year of development. ***Flowers*** about 5 cm wide with pink-purple petal-like segments (Figure 2a). ***Stamens*** with pink filaments, cream towards the base, and golden anthers. ***Style*** red, stigmas pale brownish cream to very pale yellow. ***Fruits*** solitary, never forming chains, obovoid (wider towards the apex) ripening yellow, 2–4.5 cm long (Figure 3a), with older fruits having fewer spines than younger ones. ***Seed*** not developed.

Cylindropuntia rosea may be a hybrid between *C. tunicata* and another, as yet, undetermined species (D. Pinkava

Figure 1. A large flowering *Cylindropuntia rosea* plant. Source: M. Goodwin.

personal communication). The vegetative similarity between *C. rosea* and *C. tunicata* has resulted in some confusion in the identification and management of both species in Australia in the past. In the absence of flowering material of *C. rosea*, Hosking *et al.* (2003) identified *C. rosea* as *C. tunicata*. Once flowering material was available this was corrected (Hosking *et al.* 2007).

2. *Cylindropuntia tunicata* (Lehm.) F.M.Knuth in C.Backeberg & F.M.Knuth, *Kaktus–ABC* 126 (1925).
Synonymy: *Cactus tunicatus* Lehm, *Nov. Stirp. Pug.* 1 (a): 13 (-14) (1828); *Opuntia tunicata* (Lehm.) Pfeiff., *Enum. Diagn. Cact.* 170 (1837). Common name: **Thistle cholla** in the United States of America (United States Department of Agriculture 2008) and in Victoria (Department of Primary Industries Victoria 2008). Often referred to as **Hudson pear** in the opal fields area of New South Wales, mainly due to the resemblance of this species to *C. rosea* when vegetative.

The specific epithet is derived from the Latin, *tunicatus*, having a coat or envelope, referring to the detachable papery spine sheath.

A densely branched shrub cactus usually without a trunk, older plants growing to 0.3–0.6 m high (Figure 4). ***Stem segments*** rope-like, cylindrical, pale green to green, 5–20 rarely 25 cm long, 1.5–2.5 cm wide. ***Tubercles*** prominent, 2–3 cm long. ***Areoles*** round to elliptic, 4.5–8 mm long, 2.5–5 mm wide, with a yellow-tan wool aging to white or grey and clusters of pale yellow glochids 0.5–1.2 mm long. ***Spines*** 5–12, yellow-, straw- or tan-coloured arising from most areoles, 3–6 cm long. ***Spine sheath*** yellow- to tan-coloured. ***Flowers*** about 4 cm wide and with yellow, yellow-green or yellow-pink, petal-like segments. ***Stamens*** yellow. ***Style*** green to reddish, stigmas green to yellowish green (Figure 2b). ***Fruits*** solitary, never forming chains, obovoid, ripening yellow, yellow-green or yellow-brown, often tinged red, 2.5–5 cm long, 0.8–1.5 cm wide, spineless, or with a few spines (Figure 3b). ***Seeds*** light tan in colour, oval-shaped, 2.5 mm long, 2 mm wide.

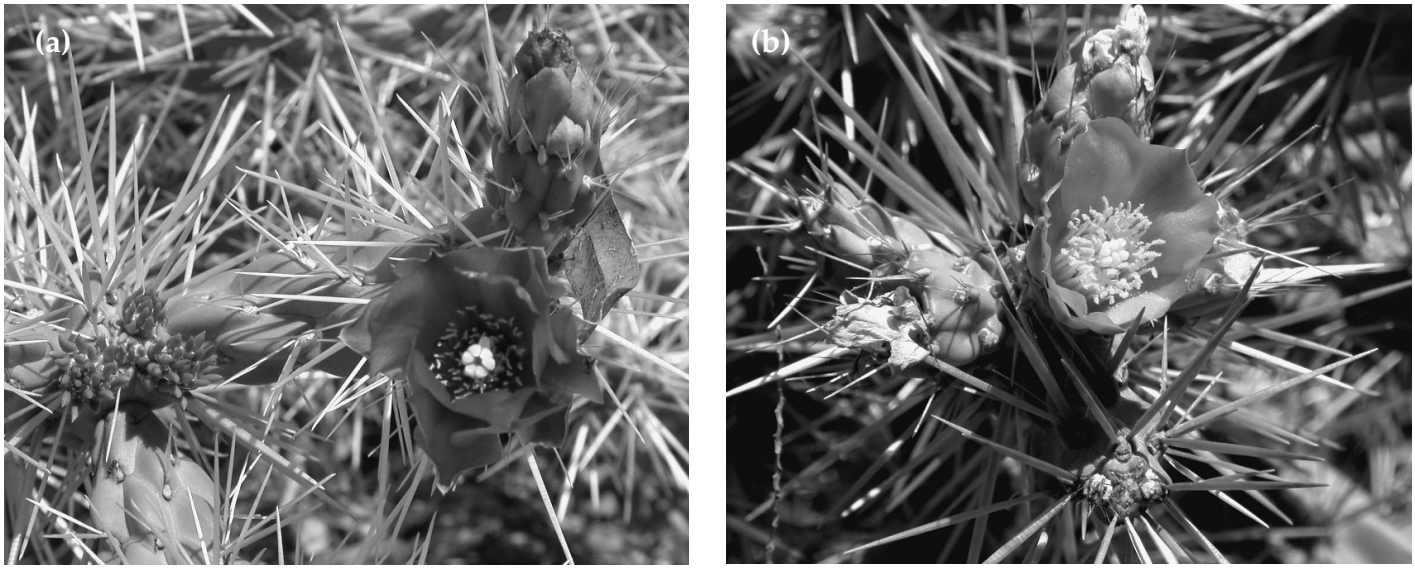

Figure 2. (a) *Cylindropuntia rosea* in flower has pink-purple flowers and long white spines (left) and (b) *Cylindropuntia tunicata* in flower has pinkish yellow flowers and straw-coloured thorns (right). Source: J. Hosking.

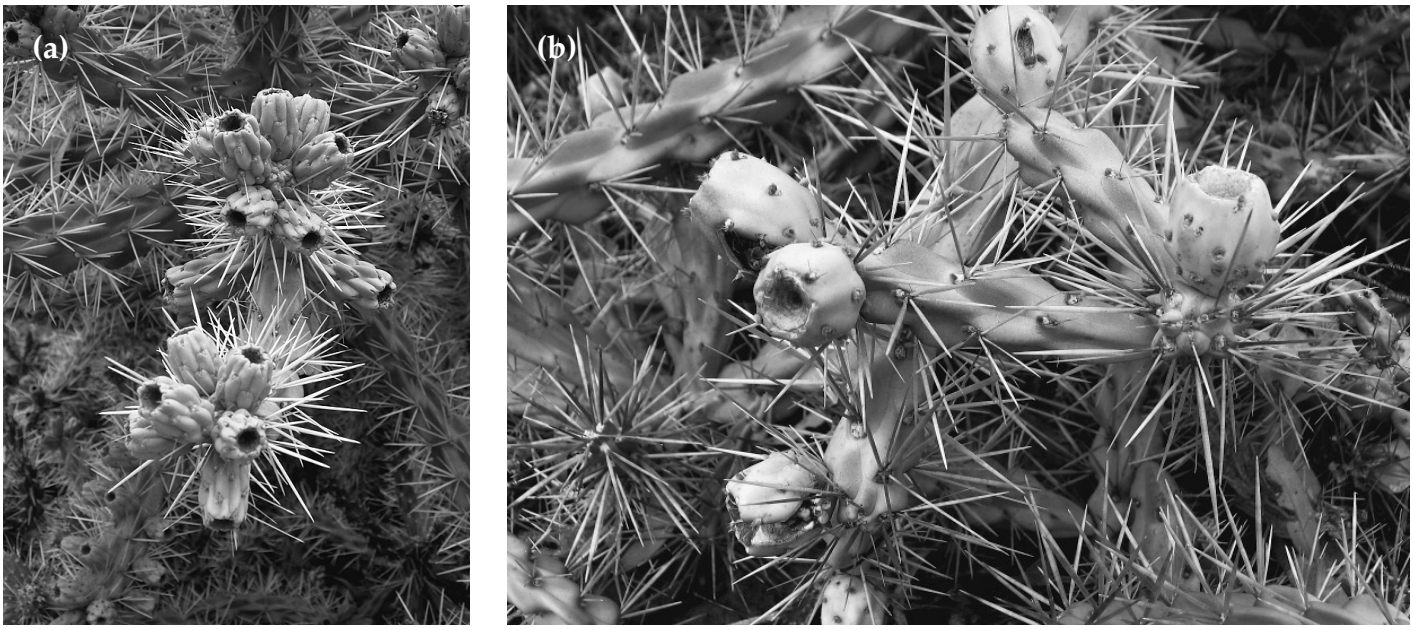

Figure 3. The fruit of (a) *Cylindropuntia rosea* (left) and (b) *Cylindropuntia tunicata* (right). Source: (a) J. Hosking and (b) R. Chinnock.

Figure 4. *Cylindropuntia tunicata* plant with fruit. Source: J. Hosking.

Distinguishing characters
Although both species co-occur in north-western New South Wales, they can be distinguished by floral and spine characteristics (e.g. Botanic Gardens Trust 2008, Figure 2). For example, *C. rosea* has pink-purple flowers in comparison to the yellow, yellow-green, to yellow-pink flowers of *C. tunicata* and the spines of *C. rosea* are white compared to the yellow-, straw- or tan-coloured spines of *C. tunicata*.

Cylindropuntia rosea and *C. tunicata* may also be confused with other naturalized *Cylindropuntia* spp. in Australia, particularly *Cylindropuntia imbricata* (Haw.) F.M.Knuth, a species with pink-purple flowers but with more rope-like segments. Confusion with *Cylindropuntia kleiniae* (DC.) F.M.Knuth, *Cylindropuntia prolifera* (Engl.) F.M.Knuth and *Cylindropuntia spinosior* (Lehm.) F.M.Knuth is also possible but distinguishing features can be seen in Anderson (2001) and at Botanic Gardens Trust (2008). The only other *Cylindropuntia* spp. known to have naturalized in Australia are *C. fulgida* var. *mamillata* (known as boxing glove cactus) and *Cylindropuntia leptocaulis* (DC.) F.M.Knuth. The former species often has fasciated/misshapen segments and the latter has pencil thin ones so they are not likely to be mistaken for either *C. rosea* or *C. tunicata*.

History
Cylindropuntia tunicata was first recorded as naturalized in South Australia from the Barmera region in 1980 (Kloot 1986) based on a collection by C. Schrank in August 1980 (State Herbarium of South Australia specimen, AD 98312157). In Victoria, the species was first recorded at Natya in 1994 (Stajsic and Carr 1996, based on National Herbarium of Victoria specimen MEL 2027309). There is an earlier record of the species occurring in Victoria at Mittayack (Hosking *et al.* 1988) but there is no specimen to back this record.

The first naturalizations of *C. rosea* and *C. tunicata* in New South Wales are likely to have occurred in the Grawin area during the late 1960s (Holtkamp 2006, L. Tanner personal communication) but *C. rosea* was considered of little concern in the early 1970s as it infested only a small area at Grawin (L. Tanner personal communication). The original introductions of *C. rosea* and *C. tunicata* to the area probably occurred from a cactus nursery at Grawin. Some reports state that 'the spread of the species was aided by opal miners who deliberately used the plants to protect their diggings from nocturnal prowlers and thieves', but these reports cannot be verified.

For New South Wales, the earliest herbarium specimen of *C. rosea* was collected from Cumborah in 2000 and the earliest specimen of *C. tunicata* was collected from Grawin in 2003 (Hosking *et al.* 2007).

The first collection of *C. rosea* in South Australia was made in 2005 near Morgan but the species was also collected in the Flinders Ranges and on Eyre Peninsula in the same year. Although most South Australian populations appear to be of recent origin, consisting of small low plants up to 30 cm high, the population near Morgan adjacent to the Murray River consists of large plants to 1.5 m high with central stems to 10 cm diameter so this population has obviously been growing for a considerable period. The species was first collected from the Menzies tip area in Western Australia in 2002 (Western Australian Herbarium specimen, PERTH 6331106), in suburban Alice Springs in the Northern Territory in 2007 (Northern Territory Herbarium specimen, DNA D0180923) and from Kapaldo-Cootharaba Station in Queensland in 1973 (Queensland Herbarium specimen, BRI 12884).

Accurate identification of both *C. rosea* and *C. tunicata* in New South Wales first occurred in 2003 following collection of flowering material by Wayne Cherry and John Hosking. These identifications were confirmed when specimens were sent to Don Pinkava (herbarium of Arizona State University) for identification in 2004. Subsequently information and duplicate specimens from these collections have been used to identify, or confirm identification, of these species in other states.

Although both species are invasive in the opal mining areas in northern New South Wales, the predominant problem is *C. rosea*. Increased funding for herbicide control has resulted in significant reductions in the density of infestations, particularly of *C. rosea* in the immediate vicinity of Lightning Ridge and the Grawin and Glengarry areas (Walgett Shire Council 2008).

Distribution
Native range
Both *C. rosea* and *C. tunicata* are native to Mexico, where *C. rosea* is most abundant in the central states of Hidalgo, Mexico, Puebla and Tlaxcala. The native range of *C. tunicata* also extends to the southern United States of America (Texas). It is found in Ecuador and Chile, but Anderson (2001) considered that it was not native to South America and was probably carried there by humans or livestock.

Australia
Confirmed naturalizations of *C. rosea* have been recorded in north-western New South Wales (NSW), South Australia (SA) (from the Flinders Ranges south to Morgan), Western Australia (WA), the Northern Territory (NT) and Queensland (QLD) (Figure 5a).

In NSW, this cactus has naturalized on the north western slopes and plains and major infestations occur around the opal fields of Lightning Ridge (29°26'S, 147°59'E), Grawin (29°38'S, 147°40'E), Glengarry (29°40'S, 147°37'E), and in the Cumborah area (29°45'S, 147°46'E). Current estimates of heavily infested areas range from 60 000 to 111 000 ha, although scattered plants are likely to be found throughout a much larger area, potentially up to 458 000 ha (Holtkamp 2006, Walgett Shire Council 2008). Smaller infestations in NSW have also been reported around Brewarrina (29°58'S, 146°52'E), at the 'Five ways' (31°09'S, 148°48'E) south east of Coonamble, and Goodooga (29°17'S, 147°02'E). Continued spread occurs in opal mining areas despite the requirement that miners rehabilitate sites after mining

has finished. Rehabilitation is meant to include removal of weeds, an activity that rarely occurs (Braysher 2005).

A number of infestations first thought to be *C. tunicata* in SA have been confirmed as *C. rosea*. These first records of this species in SA, all reported in 2005, include populations west of Port Augusta (32°30'S, 137°46'E), at Iron Baron (33°00'S, 137°09'E) and south east of Morgan (34°02'S, 139°40'E). These populations have been chemically treated.

Cylindropuntia rosea has also naturalized at the rubbish tip near Menzies, WA (29°42'S, 121°02'E, Hosking *et al.* 2007) and in suburban Alice Springs in the NT (23°41'S, 133°54'E). In QLD there are unconfirmed reports of its presence around opal mining areas (Holtkamp 2006) and herbarium specimens collected from the rubbish dump at Kalpaldo–Cootharaba Station (24°55'S, 151°05'E) and along fencelines near Mundubbera (25°36'S, 151°18'E). *C. rosea* is also reported as growing alongside the Ross Highway south east of Alice Springs in the NT (G. Grimshaw personal communication).

In contrast, the only naturalizations of *C. tunicata* in NSW occur around the Grawin opal fields (29°38'S, 147°40'E) and appear to be near original plantings of the species (Hosking *et al.* 2007, Figure 5b). In addition, naturalizations of *C. tunicata* occur at Natya in north-western Victoria (VIC) (34°57'S, 143°13'E) and on Calperum Station, north east of Renmark in SA (34°03'S, 140°47'E) (Australia's Virtual Herbarium 2008).

Naturalized range outside Australia

Cylindropuntia rosea has also naturalized in Spain (Sanz Elorza *et al.* 2004) and South Africa (H. Zimmerman personal communication) while *C. tunicata* appears to have naturalized in Chile and Ecuador (Anderson 2001, Pinkava 2004), South Africa (Hosking *et al.* 2007) and Spain (M. Sanz Elorza personal communication). At one time the name *Opuntia rosea* Engelm. was misapplied to *Cylindropuntia fulgida* var. *fulgida* (Schott ex Engelm.) Backeb. in South Africa (Henderson 2001), so much of the South African information on *O. rosea* actually refers to *C. fulgida*, for example in Zimmermann (1978) and Henderson (1995). *C. fulgida* var. *fulgida* is not known to be present in Australia.

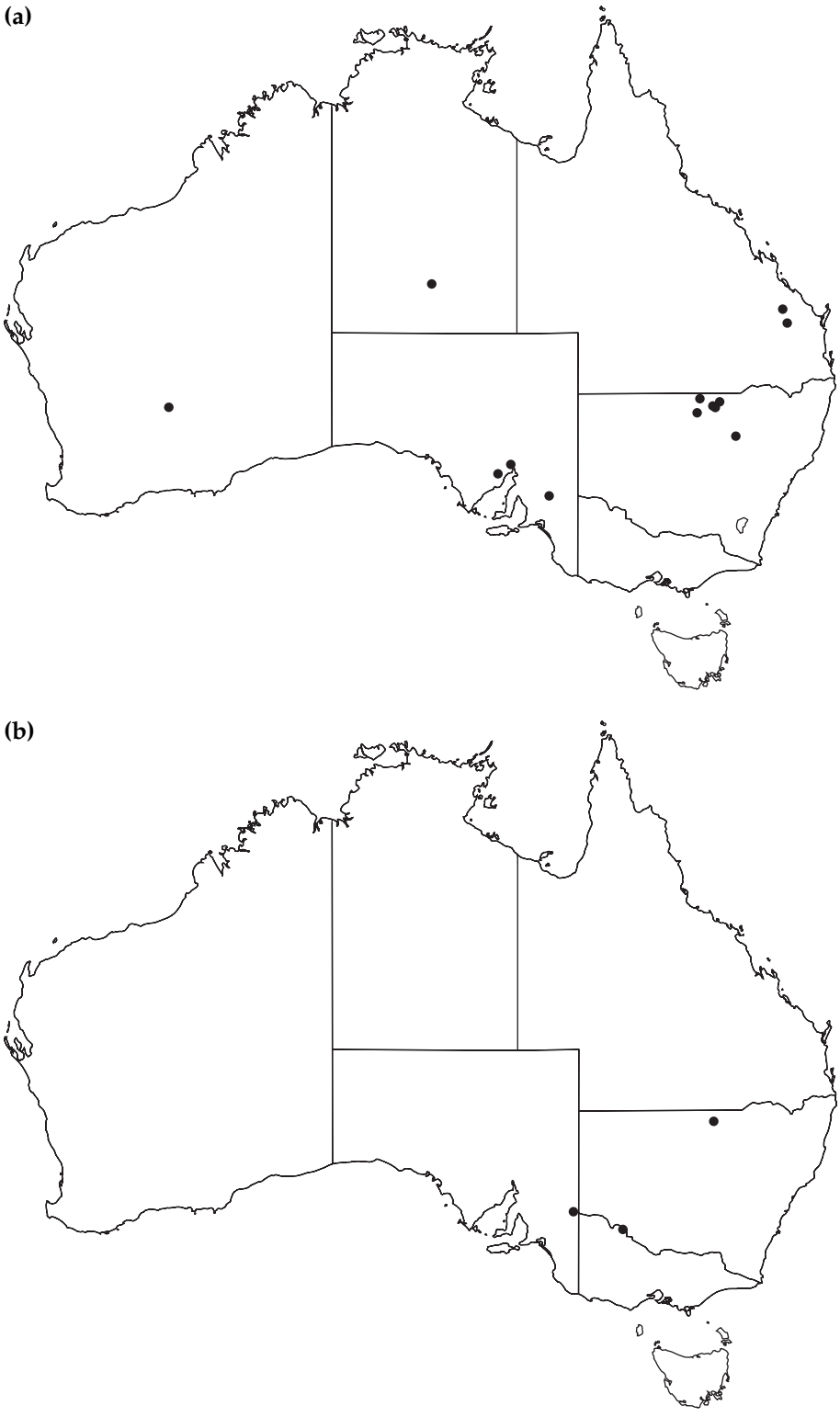

Figure 5. Distribution of (a) *Cylindropuntia rosea* (top) and (b) *Cylindropuntia tunicata* (bottom) based on herbarium records from Australia's Virtual Herbarium (2008) and personal observations of the authors. Drawn by A. Maguire.

Habitat

Climatic requirements

Although specific climatic requirements have not been investigated, both *Cylindropuntia* species are found in areas of north-western NSW receiving 400–500 mm of mean annual rainfall and with mean monthly maximum and minimum temperature ranges of 17–36°C and 4–22°C respectively.

Cylindropuntia rosea and/or *C. tunicata* have established in far drier conditions in the NT, SA, WA and VIC, with naturalized populations in areas receiving 250–350 mm mean annual rainfall. Mean monthly maximum and minimum temperature ranges are similar to those above.

Soils

In north-western NSW, *C. rosea* is common on the lighter, stony, red earths, often found on slightly raised ridges off the surrounding riverine floodplains (Figure 6). The species also invades heavier and deeper grey clays of the floodplains (Figure 7).

C. rosea grows up to 1.6 m high on these deeper more fertile soils, but rarely reaches above 1 m on the shallow red earths. One record from SA indicates *C. rosea* can grow on talus slopes on light brown calcareous loams below limestone cliffs, while in the NT plants have been found at the base of a gneiss hill. *C. tunicata* grows on red brown clay loams and compacted brown loams in SA, while in NSW it grows on the lighter, stony, red earths and on heavier and deeper grey clays of the floodplains.

Plant associations

Both *Cylindropuntia* species have been recorded as naturalized in a variety of habitats including mixed *Eucalyptus* woodland on alluvial floodplains (Figure 7), chenopod shrubland and on rocky outcrops (Holtkamp 2006, Hosking *et al.* 2007). Both species are invasive in woodland and scrub areas of north-western NSW and in grazing areas of predominantly native species or areas sown to exotic grasses and herbs.

In SA, *C. rosea* is associated with *Eucalyptus camaldulensis* Dehnh. woodland; near Port Augusta it occurs in *Maireana sedifolia* (F.Muell.) Paul G.Wilson low shrubland with scattered *Acacia papyrocarpa* Benth., *Atriplex vesicaria* Heward ex Benth., *Carrichtera annua* (L.) DC. and *Enchylaena tomentosa* R.Br., and at Iron Baron it was growing on wasteland with *E. tomentosa* and *Maireana brevifolia* (F.Muell.) Paul G.Wilson. In the Northern Territory, *C. rosea* is associated with *Acacia tetragonophylla* F.Muell. and *Pennisetum ciliare* (L.) Link (synonym *Cenchrus ciliaris* L.).

In SA, *C. tunicata* was found growing on Calperum Station in *Eucalyptus* woodland over *Eremophila longifolia* (R.Br.) F.Muell. shrubland and also on flats above the creek in *Eucalyptus largiflorens* F.Muell. woodland. At that site it was associated with *Atriplex lindleyi* Moq., *E. tomentosa*, *Sclerolaena* sp. and *Mesembryanthemum nodiflorum* L.

Growth and development

Phenology

New plants of both species arise when vegetative segments of any size, flowers or fruit contact the ground and root (Holtkamp 2006, Figure 8). For more information on reproduction see the following section.

Flowering of *C. rosea* and *C. tunicata* has been recorded in late spring and summer. Rapid growth of both species occurs after rainfall at warmer times of the year.

Reproduction

Cylindropuntia rosea is not known to produce viable seeds (Hosking *et al.* 2007). In contrast, seed is produced by *C. tunicata*, but it is probably not a significant source of dispersal as the fruit does not appear to be eaten by Australian animals and the seed does not separate from the fruit (Hosking *et al.* 2007).

Segments and fruit of both species are easily detached from parent plants. Fragments are moved through adhering to animals including livestock e.g. sheep, cattle and horses, native species e.g. kangaroos and koalas, feral animals e.g. rabbits, and domestic or working animals, e.g. cats and dogs. Accidental movement of fragments occurs when spines become attached to tyres and other parts of vehicles or machinery (Figure 9). Intentional movement of the species as garden plantings has occurred in the past. Unconfirmed anecdotal evidence suggests that intentional plantings were used to deter human trespass on mining claims, and to deter dog trespass along fence lines in the Goodooga area of NSW.

Vegetative segments are moved by overland water flows and floodwaters. Such movement by water raises serious concerns regarding further spread of the species should segments move from the floodplains around the NSW opal fields into surrounding western waterways such as The Big Warrambool and the Bokhara River (and hence to the Barwon and Darling Rivers), or the Narran River and Lake (a closed water system that does not flow into the Darling River).

Importance

Detrimental

One of the most significant problems with both *C. rosea* and *C. tunicata* is the large number of long sharp spines, which can cause human injury and economic loss. The tips of these spines have barbs that aid spine attachment. Fragments of the

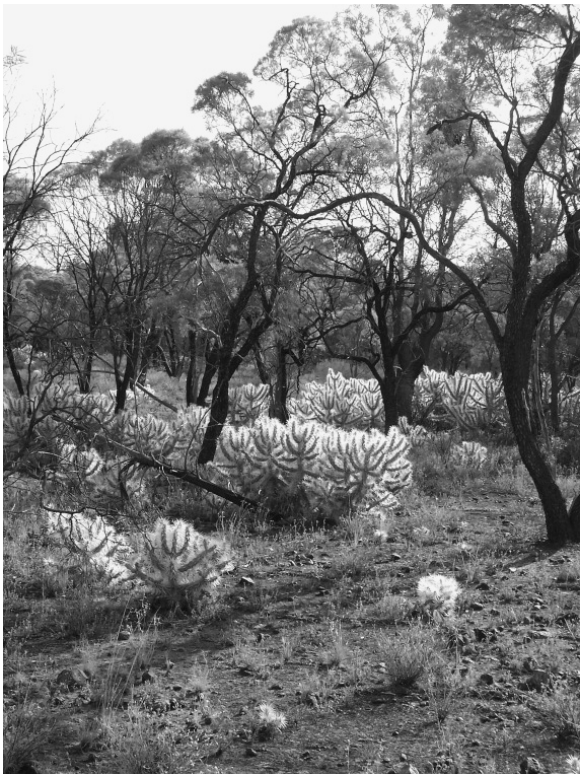

Figure 6. *Cylindropuntia rosea* is common on lighter, stony red earths around the opal fields in north-western New South Wales. Source: S. Johnson.

Figure 7. *Cylindropuntia rosea* is beginning to invade the grey clay riverine floodplains of north-western New South Wales. Source: S. Johnson.

detachable papery sheath that surrounds the spines often remain embedded after the spine is removed, causing infection.

Spines easily penetrate human and animal flesh, footwear and tyres (Osmond 2006). Minor human injury commonly results, particularly to opal miners, pastoralists, shooters and wild game harvesters, and to tourists. Livestock injury, for example to sheep, cattle and horses, is unfortunately common. These injuries and the time needed to address them result in economic loss. Infestations thus limit grazing close to these cacti, restricting the total grazing area available and presenting problems to both livestock and the animals used to muster livestock. If left unchecked, infestations have the potential to reduce production options available for agricultural enterprises and subsequent land values (Holtkamp 2006).

These cactus species have invaded semi-arid woodland and/or grazing land and *C. rosea* presently has a significant impact on approximately 111 km^2, although scattered plants possibly occur throughout a much larger area (Walgett Shire Council 2008, Figure 7). The spiny segments of both species injure native wildlife, for example kangaroos, and have been known to cause death of koalas (Osmond 2006, Holtkamp 2006) and birds. Relatively dense infestations restrict access for native animals, displace native flora and may impact on biodiversity (Walgett Shire Council 2008, Holtkamp 2006).

Figure 8. Both *Cylindropuntia* species can grow from detached segments of any size such as the segment of *Cylindropuntia rosea* pictured with a twenty cent coin. Source: R. Holtkamp.

Figure 9. *Cylindropuntia rosea* segments adhering to a vehicle tyre. Source: G. Grimshaw.

Beneficial

It is likely that both species have been used as ornamentals in the past.

Legislation

At the time when these *Cylindropuntia* species were probably introduced to Australia, entry would not have been prohibited under various proclamations of the Commonwealth *Quarantine Act 1908.* Legal introduction under various import permits may have occurred but records of these were not available (A. Wicks personal communication).

At present, all *Cylindropuntia* species are declared Class 4 weeds across NSW under the *Noxious Weeds Act 1993*. This declaration permits local government control authorities to enforce control of the growth and spread of the species according to measures specified in a management plan. In addition, the plant may not be sold, propagated or knowingly distributed (NSW Department of Primary Industries 2008).

All *Cylindropuntia* species are prohibited from import into WA under the *Plant Diseases Act 1974* (Weeds Australia 2008).

In other states *Cylindropuntia* has not been considered as a separate genus to *Opuntia.* In many states most, or all, *Opuntia* spp. are not permitted to be sold or have to be controlled (Weeds Australia 2008).

Weed management

Control of *Cylindropuntia* species using herbicides is made difficult by the types of terrain and vegetation in which infestations are located (Holtkamp 2006). As the plant occurs over an extremely large area there is no possibility of eradication (see Panetta and Timmins 2004), despite the conclusion of Braysher (2005).

Accordingly, it is important that integrated control measures be implemented, based on herbicides and other control measures, the introduction of effective biological control agents and the prevention of spread of the species. In particular, core infestations would best be dealt with using biological control agents whilst targeting outlying areas with herbicides or physical removal. Biological control agents, once established, would form self-perpetuating populations and gradually spread throughout the distribution of the

species. An integrated weed management approach of this kind allows resources to be directed to prevention of spread from outlying infestations (Holtkamp 2006).

Herbicides

Total coverage of plants is required when using herbicides as any missed plants or segments can form new infestations (Holtkamp 2006, Figure 10). The addition of a marker dye to the spray mix is helpful in determining which plants have been sprayed. Thorough spraying with herbicide mixtures incorporating a spray oil is effective at any time of the year if the plants are actively growing and not stressed. Spray failures are often observed when there is less than complete herbicide coverage on plants or when herbicide mixtures in water are used, possibly because evaporation occurs too quickly.

Plants sprayed during cooler months may take longer to die than those treated during warmer months. Herbicide application is not recommended shortly before any likely flooding event.

Three herbicides are currently registered in NSW for treating Cactaceae, including these species under the Australian Pesticides and Veterinary Medicines Authority permit number 10544 (Australian Pesticides and Veterinary Medicines Authority 2008). This permit allows the application of the herbicides Garlon 600 (600 g L^{-1} triclopyr), Grazon DS (100 g L^{-1} picloram + 300 g L^{-1} triclopyr) and Grazon Extra (100 g L^{-1} picloram + 300 g L^{-1} triclopyr + 8 g L^{-1} aminopyralid) as high volume and knapsack applications in certain agricultural and environmental areas according to label directions. Care is needed to prevent off-target damage.

Anecdotal evidence suggests that staff from the Prickly Pear Destruction Commission (later in the NSW Department of Agriculture and now NSW Department of Primary Industries) commonly applied a range of other, previously registered herbicides/mixtures to *Opuntia* and *Cylindropuntia* species present in the Lightning Ridge area before control of cactus was handed over to councils in 1988 (G. Grimshaw personal communication). Although specific trials on the efficacy of various herbicides on *C. rosea* and *C. tunicata* plants were not conducted, reports suggest that the species were at least partly controlled by these actions. This suggests that other herbicidal active ingredients and/or mixtures of these may be effective, but further trial work is needed so that permits or registrations can be pursued.

Since herbicide application is rarely 100% effective, treated sites require monitoring for regrowth and missed plants, and follow-up applications as necessary (Holtkamp 2006). Although *C. rosea* spines on large segments and plants have a shiny-silvery appearance (particularly when observers look into the sun, Figure 6), the smaller grey-green fragments and white/silvery spines and sheaths often blend in with dead leaf and grass material on the ground, and standing dead vegetation (Figure 8). As a result, systematic checking of sprayed sites is recommended.

Figure 10. Untreated *Cylindropuntia rosea* segments that collapse to the ground after herbicide application can regrow (note dead plant in centre). Source: S. Johnson.

Other treatments

Isolated plants and small infestations may be dug up and removed by hand. While such removal is successful, the danger of physical injury should be considered. Care is also needed to remove all segments from the area and to ensure that none is attached to clothing or footwear. Uprooted plants must be disposed of through burying or burning to avoid new infestations arising from this material (Holtkamp 2006). Adequate depth for burying has not been determined although some opal miners dispose of plant material down disused mine shafts. Burnt material requires checking for any regeneration. Deep freezing at –18 to –20°C for at least 48 hours is also effective for small quantities of material.

Physical removal of larger infestations is not practical unless there is follow-up because any missed plants or plant parts can form new infestations if they come into contact with the ground and form roots.

Natural enemies

The prospects for successful biological control of both *C. rosea* and *C. tunicata* are good as previous biological control programs targeting species in the Cactaceae have proven highly successful (Holtkamp 2006). *Dactylopius tomentosus* (Lamarck), a species of cochineal insect introduced for *C. imbricata*, attacks *C. rosea* but is not particularly damaging. Recent South African research has shown that there are several biotypes of *D. tomentosus* present in Mexico, at least one of which is likely to be more damaging to *C. rosea* and *C. tunicata* (H. Zimmerman personal communication). There should be few host specificity issues associated with the introduction of additional *D. tomentosus* biotypes as there are no native Cactaceae species in Australia. Additionally, *D. tomentosus* is already present in Australia so relatively little quarantine testing should be required prior to release of a different biotype of this insect. Cochineal insects used to control cactus all appear to be very specific and this is likely to be the case with the biotype for these *Cylindropuntia* species.

Prevention

Vigilance is a key means of preventing further spread of these species (Osmond 2006). In infested areas, vehicles should not leave designated roads. If this is unavoidable then the tyres and undercarriage should be checked thoroughly and any segments of *C. rosea* or *C. tunicata* removed before leaving the infested area. It is also important that clothing, footwear, other equipment and the inside of vehicles be checked in case transfer has occurred (Osmond 2006, Holtkamp 2006). Stock and other animal movement through infested areas should be minimized and any segments attached to animals should be removed before livestock are shifted to new areas.

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