Review

The biology of Australian weeds 48. *Macfadyena unguis-cati* (L.) A.H. Gentry

Paul O. Downey[A] and **Ian Turnbull**[B]
[A] Pest Management Unit, Parks and Wildlife Division, Department of Environment and Conservation (NSW), PO Box 1967, Hurstville, NSW 1481, Australia. Email: paul.downey@environment.nsw.gov.au
[B] Bellingen Shire Council, PO Box 117, Bellingen, NSW 2454, Australia.

Name

The genus *Macfadyena* A. DC. (syn. *Doxantha* Miers, family Bignoniaceae) includes four species of woody vines all native to tropical Central America and northern South America (Spangler and Olmstead 1999, Wagner *et al*. 1999).

Macfadyena unguis-cati (L.) A.H. Gentry (syn. *Bignonia unguis* L. emend. DC., *B. unguis-cati* L., *B. tweediana* Lindley, *Batocydia unguis* (L. emend. DC.) Mart. ex DC., *B. unguis-cati* (L.) Mart. ex Britt., *Doxantha unguis* (L. emend. DC.) Miers, *D. unguis-cati* (L.) Miers ex Rehd., *D. praesignis* Miers, *D. serrulata* Miers) (cat's claw creeper, cat's-claw climber, cats-claw vine, catclawvine, cat's claw, claw vine, yellow trumpet vine, cat claw ivy: hereafter described by its main common name cat's claw creeper, due to the tendrils resembling the claws of a cat, Figure 1a).

Description

Cat's claw creeper is a perennial, woody climbing vine or occasionally a scrambling shrub/ground cover. It is capable of climbing most surfaces, with the aid of tendrils which terminate in three hardened hooks (Acevédo-Rodriguez 1985). Once attached, these climbing appendages or tendrils anchor the plant and allow it to grow vertically. In the absence of climbing support, individual stems grow along the ground where they smother ground vegetation. As stems grow over each other, dense mats form which then prevent recruitment/regeneration of other species (Muyt 2001).

Young stems are red-brown or bronze in colour, turning green and woody with age, with a maximum diameter of 15-20 cm (Muyt 2001, T. Moody personal communication). The lianas, or woody climbing stems, are strong, flexible, cylindrical, glabrous or nearly so, and can reach 20 m in length (Wagner *et al*. 1999). Stems appear to intertwine and then grow together as a 'single larger diameter' stem, aiding their climbing ability (T. Moody personal communication). The liana contain many lenticels (Francis n.d.a) and often produce roots at the nodes (Wagner *et al*. 1999); these adventitious aerial roots attach to and can penetrate the outer bark of the host plant (G. Vivian-Smith personal communication), aiding in anchoring the plant tightly to vertical surfaces as it climbs (Francis n.d.a). Older plants, however, may become more or less free hanging as these climbing devices (tendrils and aerial roots) senesce (Muyt 2001).

The leaves are opposite, compound, with two leaflets 3–7 cm long, ovoid to lanceolate 1–3 cm wide with entire margins, and a terminal three-forked tendril (Figure 1a, Muyt 2001). The leaves are discolorous – dark green above and lighter green below. Mature leaves can exhibit different characteristics, being narrowly ovate to lanceolate, 5–16 cm long, 1–7 cm wide, both surfaces sparsely lepidote or covered with minute scales (Wagner *et al*. 1999). The tip of each tendril bears a small deciduous horny hook, 0.1–3.5 cm long (Wagner *et al*. 1999). The peduncles are 2 cm in length and covered with short hairs, the colour of which change with age from red-brown to dark green, discolorous being lighter below. Inflorescences are typically axillary in clusters of 1–3 (–15) flowers; calyx cup-like, 0.1–1.8 cm long, glabrous to sparsely lepidote, margins crenulate-undulate; corolla with five petals fused to greater than ¾ of length giving a trumpet like appearance, typically with a glossy sheen, yellow with *ca.* nine orange lines in the throat (Figure 1b), tubular-campanulate, 4.5–10 cm long, 1.2–2.4 cm wide at the mouth, the tube 3.3–6.9 cm long, puberulent within and along the throat ridges (Wagner *et al*. 1999).

Fruits are a flattened linear capsule, 26–95 cm long, 8–15 mm wide, inconspicuously lepidote, tapering at both ends, pendulous, initially green becoming brown/blackish with maturity (Acevédo-Rodriguez 1985, Howard 1989, Wagner *et al*. 1999). Capsules mature in late summer to autumn (January to May in Australia), splitting open along lateral seams (Vivian-Smith and Panetta 2002). Seeds are brown,

Figure 1a. Cat's claw creeper tendrils (photo: Paul Downey).

Figure 1b. Cat's claw creeper flowers, buds and leaves (photo: Paul Downey).

being flattened and oblong in shape; papery and two-winged, 1–1.8 cm long, 4.2–5.8 mm wide, the wings membranous, not sharply demarcated from the seed body, irregularly hyaline at tip (Wagner *et al*. 1999). Air-dried seeds weigh on average 0.0224 ± 0.0005 g (Turner and Wasson 1999), with similar to slightly lower values recorded in Australia (G. Vivian-Smith personal communication).

History

Initially introduced for ornamental purposes, cat's claw creeper is now widely naturalized in Australia (Floyd 1989). The first recorded occurrence of cat's claw creeper as an ornamental plant was in 1865 in a Melbourne nursery catalogue, suggesting a probable introduction date, which was followed by the occurrence in a Sydney nursery catalogue six years later in 1871. Following these initial listings, cat's claw creeper appeared in almost every Melbourne and Sydney nursery catalogue examined up until the late 1980s (Mulvaney 1991).

The first naturalization of cat's claw creeper was, however, not recorded until the 1950s in south-eastern Queensland (Batianoff and Butler 2002). Subsequent naturalizations were then observed in north-east New South Wales, for example at Wingham Brush in 1966 (Stockard 1993) and the Tabulam area of the Clarence catchment in the 1970s (T. Moody personal communication). Once naturalized, populations have expanded dramatically; for example, by the late 1970s the infestation at Wingham Brush was such that mature trees had been killed, and control is still continuing today (NPWS 2003). Infestations were also too large for individual land managers to control in the Tabulam area by the 1970s (T. Moody personal communication).

Cat's claw creeper is now widespread within coastal and subcoastal areas of southern Queensland and northern New South Wales (Swarbrick and Skarratt 1994, Csurhes and Edwards 1998), extending as far south as Bellingen (Floyd 1989) and more recently Taree. Infestations now occur in many southern Queensland and north-eastern New South Wales catchments, in particular the Nerang, Logan, Brisbane, Pine, Maroochy, Mary, Burnett, Boyne, Kolan, Baffle, Callide, Dawson, Condamine (Browne n.d.), Macleay, Clarence, Tweed, Richmond, Orara, Manning and Nambucca catchments (T. Moody personal communication). The rate of spread and establishment is such that cat's claw creeper is now considered to be one of the most invasive plants in the region (Achilles 2003) and the fourth most invasive weed in south-east Queensland (Batianoff and Butler 2002). For example, in Queensland cat's claw creeper now occurs in 61 shires; in half of these the infestation levels are increasing (Dhileepan and Donnelly 2002). The worst infestations in Australia today occur along the Clarence River, northern New South Wales, spanning approximately 150 km (T. Moody personal communication).

Examination of urban bushland in and around Sydney, Melbourne, Canberra and Adelaide during the late 1980s did not reveal cat's claw creeper populations, despite it being available in nursery catalogues for over 120 years (Mulvaney 1991). Few naturalized populations exist today in the Sydney area, despite its presence in many gardens (P. Downey personal observation). Regardless, it has been suggested that cat's claw creeper could become a weed within the Sydney region (M. Mulvaney personal communication).

Distribution

Cat's claw creeper is native to the Greater and Lesser Antilles, Mexico, Central America and South America to Argentina (Howard 1989).

In Australia, cat's claw creeper has become widely naturalized on the east coast, where the majority of infestations occur from Sydney through to Rockhampton (Figure 2b), with major infestations occurring from Taree to the Sunshine Coast. Although cat's claw creeper has a preference for tropical and subtropical climates, it has also established populations in temperate regions (i.e. the New England Tablelands and the Clarence). Recent collections have identified new infestations, particularly in Mareeba and the surrounding Atherton Tablelands of far north Queensland. Collections of naturalized plants have also been made around Darwin, Melbourne and on the Western Australian side of the Great Australian Bight (AVH 2004). Cat's claw creeper has been recently acknowledged as potentially naturalized in Victoria, with several wild populations now present in that state (Ross and Walsh 2003). In the Northern Territory cat's claw creeper was first recorded as naturalized near the Darwin Botanic Gardens. However, due to poor flowering and redevelopment of several of the sites in which it occurred its spread has been limited (A. Mitchell personal communication).

Predictions of cat's claw creeper potential distribution made in 1999 (Figure 2a) were revised in 2003 to include Western Australia and Northern Territory (see Groves *et al.* 2003) following the collection of plants from new locations. However, recent collections, especially from northern Queensland, have led to yet another prediction of the potential distribution (Figure 2b).

In the USA cat's claw creeper was first recorded as naturalized in southern Florida in 1971 (Long and Lakela 1971) and northern Florida in 1988 (Godfrey 1988, Hall 1993) after a lag of 40 years, being first introduced prior to 1947 (Bailey and Bailey 1947). By 1996 it had been recorded as naturalized in 11 counties within Florida (see Wunderlin *et al*. 1996). Langeland and Craddock Burks (1998) go further and state that cat's claw creeper is invasive, rather than simply naturalized, throughout Florida.

In addition to Florida, cat's claw creeper is also a major environmental weed in south-eastern USA, particularly in the states of Texas, Louisiana (APCOSC 2001), Alabama, and South Carolina (Meyer *et al*. 1994), the Caribbean, particularly Puerto Rico and the Virgin Islands as well as the Bahamas (BEST n.d.). It has also become invasive in India, and the islands of Mauritius and St. Helena (Holm *et al*. 1991). It has become naturalized and is becoming a major weed in the Limpopo, Mpumalanga and Kwa Zulu-Natal regions of South Africa (Sparks 1999a,b, Iziko 2004), as well as in Kruger National Park (Foxcroft and Richardson 2003). Elsewhere in Africa cat's claw creeper is reported as naturalized in Zimbabwe, particularly around Harare (Diniz 1988, Hyde 2003). It is also recorded on the Pacific Islands of New Caledonia (Meyer 2000 – recorded as moderately invasive), Niue (Space and Flynn 2000), the Cook Islands (Space and Flynn 2002) and New Zealand (J. Craw personal communication), where it was declared as an unwanted organism in 2001 (Anon. 2001). In Hawaii, cat's claw creeper was first recorded as naturalized on the island of Hawai'i in 1999 (Imada *et al*. 2000); it also occurs on the islands of Kaua'i, O'ahu, and Lána'i (Wagner *et al*. 1999), and Maui (Wagner *et al*. 1999, Oppenheimer and Bartlett 2000, Starr *et al*. 2002). It has recently been recorded as a newly naturalized species in Europe (de Almeida 2000). It is also recorded in the flora of Thailand (see Smitinand 1987), but there was no mention of its naturalization status in this text, and it has been reported as a weed in China (CCICED 2000).

Habitat

Climatic requirements

In its native range cat's claw creeper grows from near sea level to over 600 m in elevation, with a mean annual rainfall of 750–2400 mm (Francis n.d.a). Cat's claw creeper prefers moist and warm habitats, and it grows most vigorously in sunny positions, but is capable of growing in shady locations.

Once established, cat's claw creeper can withstand heavy frost (i.e. −10°C (Anon. 2004b)), but may lose some leaves, or in severe cases, the stems may die back to the ground and subsequently resprout from tubers (Watkins and Sheehan 1975).

Cat's claw creeper is also drought-tolerant (Desert-Tropicals 2001, Anon. 2004b, Crescent Bloom 2004), or capable of growing in desert conditions and is 'Excellent

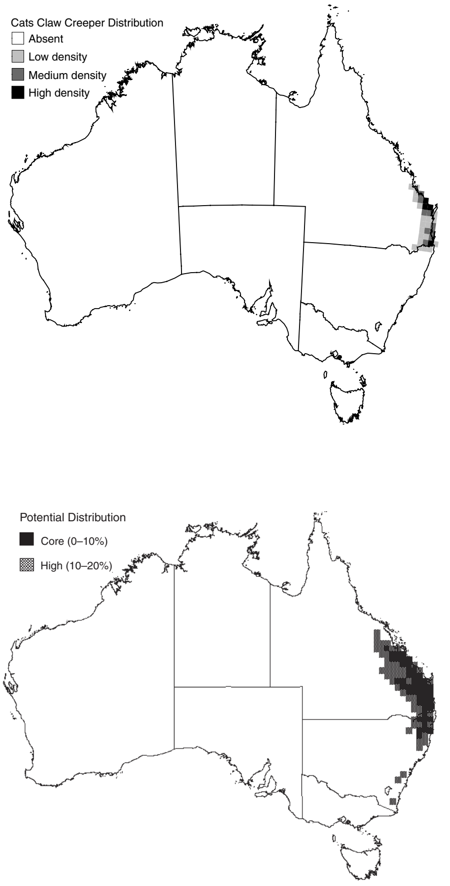

Figure 2a. The current (above) and potential (below) distribution of cat's claw creeper in Australia modelled in 1999 after Thorp and Lynch (2000).

on sunny, hot walls or fences' (see Star Nursery 2004 or Master Gardeners 2004).

Substratum

Cat's claw creeper grows best in uniform soils, either sandy or clay in origin (Master Gardeners 2004), but appears to tolerate most soil types (Morton 1971, Nelson 1996, Csurhes and Edwards 1998), with the exception of poorly drained soils (Francis n.d.a,b, Csurhes and Edwards 1998). It is also capable of growing in saline soils (Desert-Tropicals 2001, Anon. 2004a). Cat's claw creeper is capable of growing over a range of soil pH (Crescent Bloom 2004) from mildly acidic to mildly alkaline (pH 6.1–7.8, Anon. 2004b). Recent observations suggest that cat's claw creeper is capable of growing in areas with poor soil structure and fertility (T. Moody personal communication).

Plant associations

In Australia, cat's claw creeper typically invades riparian and rainforest communities in sub-tropical and tropical zones (Csurhes and Edwards 1998). However, it has recently expanded into adjacent dry sclerophyll forests (e.g. forest dominated by spotted gum, *Eucalyptus maculata* Hook.) (T. Moody personal communication). Overseas, cat's claw creeper grows in savannahs, secondary forests, and remnant high forests (Francis n.d.b). The plant communities at greatest risk from invasion are listed later in this review.

In it native range cat's claw creeper is associated with host trees that offer drier and higher light conditions (Malizia 2003), in seasonally moist or wet, non-flooded, evergreen lowland forests regions (Francis n.d.a).

Plant/animal relationships

The combined effect of infestation and mortality of trees caused by cat's claw creeper, particularly in riparian and rainforest areas, may impact upon flying-foxes through loss of roost trees and food sources (Stockard 1991). Species likely to be at risk are little red flying-fox (*Pteropus scapulatus* Peters) and the grey-headed flying-fox (*P. poliocephalus* Temminck, a vulnerable species in New South Wales).

Cat's claw creeper poses a threat to the endangered eastern freshwater cod (*Maccullochella ikea* Rowland), which is endangered both nationally and in New South Wales, especially in the Clarence River system, as loss and modification of riparian vegetation and stream banks reduces stream health and water quality, as well as reducing food and shelter (NSW Fisheries 2004). Cat's claw creeper is not specifically identified, but it is the major cause of such riparian damage in several areas where this fish occurs (T. Moody personal communication).

Growth and development

Morphology

Cat's claw creeper has an extensive root system, which produces nodes at intervals of 30–50 cm. Nodes in turn grow lateral roots, resulting in an interconnected root system (Floyd 1989, Stockard 1991, 1993, Muyt 2001). The roots of cat's claw creeper develop tubers in the second year, the number of which increases with age and depth (Csurhes and Edwards 1998). However, recent observations suggest that tubers are present on new seedlings, i.e. at the two leaf stage, being 1.5–2 cm in diameter (T. Moody unpublished data). Tubers typically reach 40 cm in length, but the maximum recorded is 6 m (Browne n.d.). In mature infestations tuber density can be as high as 938 m^{-2} or 10 million ha^{-1} to a depth of 30 cm (Achilles 2003), but tubers can occur up to 1 m below the soil surface. Such tuber densities and the associated root biomass are likely to pose significant root competition with other species (Stockard 2001) and even a barrier to restoration, in a similar manner to other tuberous vines (e.g. Turner *et al*. 2006). In floodplain infestations, the deposition of alluvium can result in a layering of root systems, compounding the competitive effect of cat's claw creeper as well as hampering

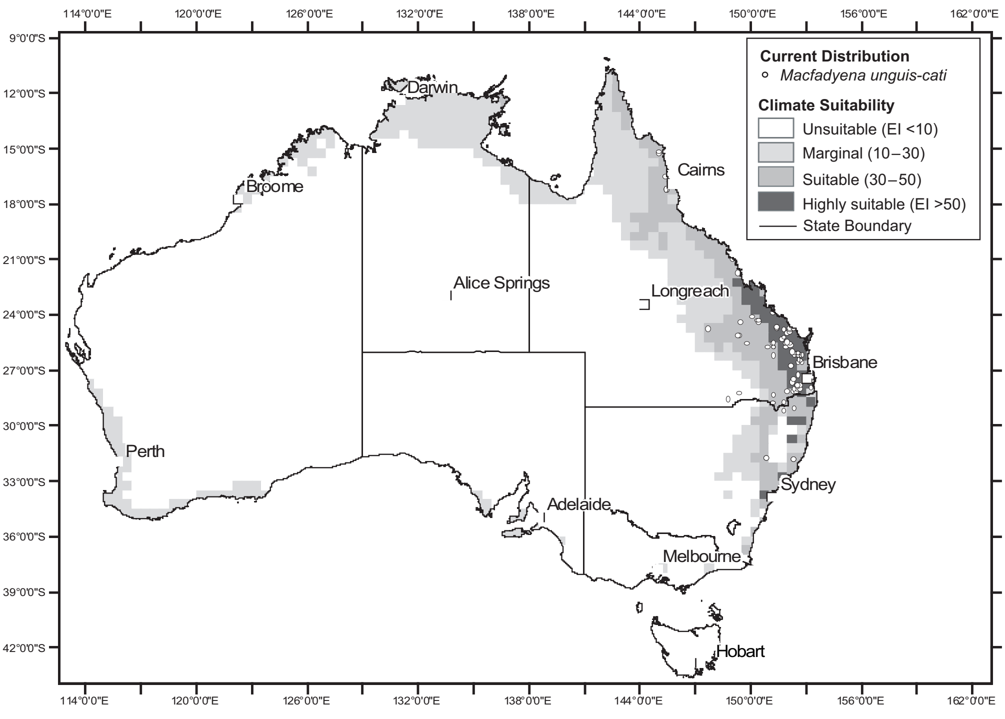

Figure 2b. The current and potential distribution of cat's claw creeper modelled in 2005 based on new populations, especially in north Queensland (map produced using CLIMEX by Moya Calvert).

control options (Stockard 1991). Multiple stems emerge from each tuber, which, when combined with the high density of tubers, can result in a very high number of stems. For example, 586 individual stems have been recorded ascending a single mature rainforest tree (Stockard 2001).

Growth rates

Growth rates vary depending on plant age and environment, although there are no data available on growth rates *per se*. Cat's claw creeper has a prolonged seedling stage. This enables enlargement of roots and tubers, which it then draws upon to grow rapidly, thus aiding its ability to climb (Godfrey 1988). Such rapid grow is especially present in young plants or new stems (Swarbrick and Dreier 1996). Increased growth rates are associated with increased light levels, both in terms of increased daylight hours and growing into lighter conditions (Swarbrick and Dreier 1990). Stems grow vigorously in length, but stem diameter expansion is slow (Francis n.d.a) and because stems do not produce growth rings (Figure 3), it is not possible to estimate plant age.

In the native range cat's claw creeper has a superior ability to climb host trees compared with other vine species, because most lianas with a twining habit are unable to climb trees with a diameter greater than 20 cm (Putz 1980). However, cat's claw creeper's ability to climb is not impeded by the diameter of host trees (Putz 1980).

Perennation

Cat's claw creeper is an evergreen perennial which appears to be long-lived, although there is a lack of information concerning its longevity. It has a well defined growing period extending through spring and autumn (September to May in Australia, I. Turnbull personal observation). Young plants are moderately shade tolerant, capable of growing under both full sun and forest canopies (Morton 1971, Nelson 1996). The level of shade tolerance appears to decrease as the plant ages from a sapling to a mature plant (Francis n.d.a,b). In shade, plant growth is slow and few branches are produced, but this changes dramatically once the growing tips reach light (Francis n.d.a,b, Floyd 1989). It appears that this accelerated growth triggers some kind of activation in the tubers which in turn produce new lianas that ascend the host tree (Floyd 1989).

Physiology and genetics

The presence of multiple seedlings from a single seed indicates that cat's claw creeper may be facultatively apomictic (Panetta 2003). Production of seeds by asexual means allows well-adapted gene combinations to be reproduced without recombination of DNA, which may result in increased competitiveness (Raven *et al*. 1998). Cat's claw creeper has both diploid ($2n = 40$) and tetraploid ($2n = 80$) populations (Acevédo-Rodriguez 1985, Gentry 1983, Howard 1989, Liogier 1995), and gene sequences have been lodged with GeneBank (see Cahoon *et al*. 1998). In addition a phylogenetic analysis of the Bignoniaeceae has been undertaken using the *cp*DNA gene sequences *rbc*L and *ndh*F1 (Spangler and Olmstead 1999).

Examination of root-pressure in cat's claw creeper showed that root-pressure was absent (Fisher *et al*. 1997). Lack of root-pressure is thought to limit vine species to tropical and sub-tropical regions of the world, as root-pressure helps to fill embolized vessels in the lianas, which if unfilled could freeze during low temperatures, thus killing the plant (Fisher *et al*. 1997). However, cat's claw creeper is capable of withstanding heavy frost (Watkins and Sheehan 1975).

Phenology

Cat's claw creeper flowers in spring in Australia as well as elsewhere in its exotic range (e.g. Hawaii, Rauch and Weissich 2000), with a peak in early spring. However, in some locations in the native range there are two flowering periods (e.g. Puerto Rico, both in the dry season (Acevédo-Rodriguez 1985)). Examination of flowering patterns in the native range revealed a single short flowering period of four weeks following rainfall in April-May (see Opler *et al*. 1976); the second flowering period is typically reduced (Gentry 1974, 1983). Initial flowering may not occur until the plant is well established (Odenwald and Turner 1980).

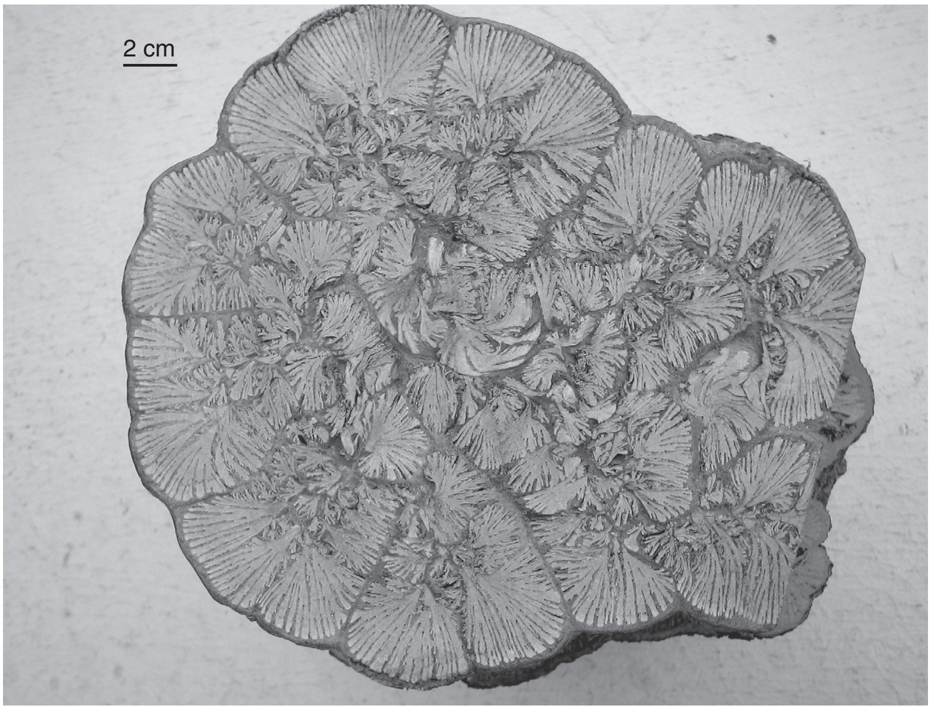

Figure 3. Cross-section of cat's claw creeper stem (photo: Paul Downey).

Reproduction

Pollination

The only study of pollination in cat's claw creeper, from Costa Rica, showed that large anthophorid bees were primarily responsible for pollination (Opler *et al*. 1976).

Seed production and dispersal

Cat's claw creeper produces long thin fruits or capsules, which mature within six months after fertilization (Francis n.d.b). Capsules can contain between 106–212 seeds (Turner and Wasson 1999). Examination of seed deposition rates showed a seasonal peak in August, with an average rate of 167 seeds m^{-2} $year^{-1}$ directly under cat's claw creeper canopies (G. Vivian-Smith personal communication).

The seeds have membranous wings that are not sharply demarcated from the seed body (Harden 1992). These wings aid the dispersal of cat's claw creeper seeds; the primary dispersal mechanisms are wind and water (Gentry 1983, McClymont 1996, Wagner *et al.* 1999). Interestingly, a relative of cat's claw creeper, *M. uncata* (Andrews) Sprague & Sandwith is water dispersed and has a distribution restricted to swamps and streamsides, and a similar geographic range to cat's claw creeper in its native range (Gentry 1983). Information on seed dispersal is limited, but the prevalence and increasing spread of cat's claw creeper along riparian corridors implies that water may play an important role in its dispersal; wings on seeds can also be useful for water dispersal (Thebaud and Debussche 1991). Cat's claw creeper seeds are capable of floating in water for up to 54 days, with 50% floating after 36 days (Vivian-Smith and Panetta 2002). In addition, the capsules can also float, but the maximum period of flotation is only 16 days (Vivian-Smith and Panetta 2002).

Germination
Germination of cat's claw creeper in the field has been examined in two studies. Vivian-Smith and Panetta (2004) found that seedling emergence did not start until 52 days after sowing, with the majority of seedlings being recorded between 100 and 260 days. Growing conditions may explain the differing results of Turner and Wasson (1999), where 100% of cat's claw creeper seeds germinated between 49–95 days following sowing.

Emergence ceased after 300 days for seeds on the soil surface, or buried at 1 cm and 5 cm depths, even though observations continued for a further 300 days (Vivian-Smith and Panetta 2004). Seedling emergence was highest at the soil surface and lowest at 5 cm, attaining a maximum of 50% and 25%, respectively. Seed banks and seed viability are low and highly variable, based on samples taken six months apart (Vivian-Smith and Panetta 2004). Seed dormancy is very low, being between 5 and 15% for fresh seed (Panetta 2003).

In a controlled experiment using growth cabinets, germination peaked between 21–28 days at 20/30°C (minimum/maximum), 28–35 days at 15/25°C and 42–49 days at 10/20°C, with germination continuing until the experiment finished at 119 days (Vivian-Smith and Panetta 2004). Forty-two percent of seeds produced multiple seedlings, with the maximum number of seedlings being four (Vivian-Smith and Panetta 2004). Germination was not influenced by the absence of light, except under low temperatures (i.e. 10/20°C) (Vivian-Smith and Panetta 2004); reduced germination under low temperatures may explain why cat's claw creeper has not widely naturalized in cooler climates (Buchanan 1989). Germination is not influenced by immersion in water (Vivian-Smith and Panetta 2002), but a dense cover of plant material can limit germination and subsequent survival of cat's claw creeper seedlings (Stockard 2001). However, cat's claw creeper seeds germinate readily in moist leaf litter (Swarbrick and Dreier 1990).

Vegetative reproduction
Cat's claw creeper is capable of vegetative reproduction, with new plants growing from each root tuber, or from tubers that develop at the leaf nodes (Stockard 1993, Sparks 1999b); new plants also form when tubers are separated from the parent plant (Sparks 1999b). Vegetative reproduction is so effective it is used to propagate plants in the horticultural industry (Master Gardeners 2004). In addition, cat's claw creeper vines growing along the ground are capable of rooting at leaf nodes and cuttings are capable of rooting (Turner and Wasson 1999, Anon. 2004a).

Hybrids
There are no known hybrids.

Population dynamics
There have been no published studies to date on demography or population dynamics of cat's claw creeper from either its native or exotic range.

Importance
Detrimental
In its native range, cat's claw creeper appears to have little impact on its host trees, despite being the dominant climber in some areas (Malizia 2003). However, in the exotic range cat's claw creeper can have significant impacts on host trees, including mortality (FEPC 2001, Stockard 2001), which is one of the main reasons it is considered a major environmental weed (Dickey 1968, FLEPPC 1996). Mortality does not typically occur until cat's claw creeper reaches the upper sections of the host tree. Its ability to grow in low light levels allows it to spread within intact canopies (Stockard 1991), which results in the initial loss of lateral host branches, mainly due to the weight of the vines, or high winds (T. Moody personal communication). This loss of branches reduces the ability of the host to photosynthesize, while cat's claw creeper shades out large patches of the remaining canopy (Stockard 2001). This process often results in cat's claw creeper turning mature trees into vine covered stags or 'green poles', which eventually collapse under the weight of the vines. Opening of the canopy can promote the invasion of more light-demanding species (QDNRM 2004), or further invasion by cat's claw creeper.

The acknowledgement of cat's claw creeper as one of the 71 weeds considered during the Weeds of National Significance initiative (Thorp and Lynch 2000) highlights its current and potential status as one of Australia's worst environmental weeds. On a more regional scale, cat's claw creeper was ranked as the 4th most invasive weed in south-eastern Queensland (see Batianoff and Butler 2002).

The ability of cat's claw creeper to grow over most surfaces can cause serious damage in urban settings, as the tendrils and aerial roots which anchor the plant are also capable of lifting roof tiles and cladding. In addition, the weight of vines can crack walls and break fences. Consequently, the removal of cat's claw creepers can also damage such surfaces since the tendrils and aerial roots bind tightly to them (Anon. 2004b).

Cat's claw creeper poses a serious problem for forestry operations as it can stress and kill trees and is difficult to control. In addition, cat's claw creeper poses a problem to power companies and railways; it often grows up power and other poles, where it can cause localized power interruptions due to the weight of vines bringing down either the pole and/or powerlines.

The potential impact of cat's claw creeper on native species and ecosystem function is very high. For example, as it invades riparian areas a range of changes have been observed which include death of mature trees, bank destabilization, loss of habitat for a range of native species (T. Moody personal communication), and intense root competition with the host tree, which may also play a role in host tree mortality (Stockard 2001). Further habitat destruction occurs from restricted germination and recruitment due to the mats of vines that smother low vegetation and prevent recruitment/regeneration (Floyd 1989, Dunphy 1991, Stockard 1991, Muyt 2001).

The native species threatened by cat's claw creeper are: brush sauropus (*Phyllanthus microcladus* Muell. Arg. – listed as endangered in New South Wales), Bennets ash (*Flindersia bennettiana* F.Muell. ex Benth), the vine *Coelospermum paniculatum* F.Muell, coast canthium (*Canthium coprosmiodes* F.Muell – see Achilles 2003) and *Pararistolochia praevenosa* (F.Muell.) Michael J. Parsons. Cat's claw creeper also poses a serious threat to species within the following ecological communities: coastal rainforests (where it is thought to pose the greatest threat (Floyd 1989)), riparian (includes *Casuarina* spp.) and rainforest communities (Floyd 1989, Dunphy 1991), and forest remnants (particularly lowland coastal subtropical rainforest and dry rainforest/scrub in sub-coastal areas). Cat's claw creeper threatens many native rainforest vines in these habitats (Floyd 1984). In addition, it threatens lowland subtropical rainforest, an endangered ecological community in New South Wales, particularly at Susan Island in northern New South Wales.

The impact of cat's claw creeper on biodiversity has recently been acknowledged through the listing of exotic vines as a Key Threatening Process under the NSW *Threatened Species Conservation Act 1995* – cat's claw creeper was identified as one of the worst vines (NSW SC 2006).

Beneficial
Cat's claw creeper was originally introduced to Australia as an ornamental, where its ability to cover fences and walls or to create a vegetative screen made it a desirable plant. The horticultural value of cat' claw creeper was initially attributed to its good establishment rate, and the apparent lack of insect and disease problems (Francis n.d.b). However, the promoters of its benefits also highlight the dangers of it becoming invasive and the need to prune

it yearly immediately following flowering, thereby limiting seed production and its ability to escape (Francis n.d.b, Master Gardeners 2004). Some authors suggest that the propensity for cat's claw creeper to naturalize and compete with native species far outweighs its horticultural value and therefore cat's claw creeper should be banned from sale in Australia (see World Wildlife Fund 2004); this should not be a difficult task given it is no longer regarded as a plant of horticulture value (see QDNRM 2004) and is currently available for sale only in the Northern Territory (World Wildlife Fund 2004). A worrying trend, however, is that cat's claw creeper is being promoted on nursery websites for desert and saline areas in the United States due to its low water requirements (DesertTropicals 2001, Anon. 2004a). Such recommendations could see a resurgence in its popularity in Australia and would likely result in a major expansion in its distribution (i.e. into dry and saline areas of Australia), given its ability to naturalize.

Outside of the horticultural sector, cat's claw creeper has been used in herbal medicines to treat manchineel dermatitis derived from *Hippomane mancinella* L. (Euphorbiaceae) (Standley 1926, Lewis and Elvin-Lewis 1977, Michell and Rook 2001). Cat's claw creeper has also been used in several other herbal medicines (Liogier 1990). In particular, it has been used as an anti-inflammatory, antimalarial, antivenereal treatment (Garcia Barriga 1975, Duarte *et al*. 2000) and to treat gastrointestrial pain (Mendoza *et al*. 2002) in folk medicine. A chemical characterization of the main plant compounds revealed antitumoral, antitrypanosomal activity and partial anti-inflammatory properties in cat's claw creeper (Duarte *et al*. 2000). Other studies have revealed the presence of saponins – the only such occurrence in the Bignoniaceae – which may account for its use in folk medicine, due to their cytotoxic activity (Ferrari *et al*. 1981). Another study showed cytotoxic activity from cat's claw creeper root extracts (Mendoza *et al*. 2002), suggesting that it may have some value in modern medicine. Care must be taken when discussing the medicinal value of cat's claw creeper, as there is another species used in folk medicine with a similar common name – cat's claw (*Uncaria tomentosa* (Willd.)DC., e.g. see Sandoval *et al*. 2000).

The seed oil of cat's claw creeper contains high levels of palmitoleic and *cis*-vaccenic acids (Cahoon *et al*. 1998). These fatty acids have been identified as potential candidates for enzyme engineering aimed at producing a new generation of crop plants containing unusual fatty acids. Thus, the occurrence of such high levels of these compounds in cat's claw creeper may be beneficial to the agricultural sector.

Legislation

In Queensland, cat's claw creeper has been declared a class 3 species under the *Land Protection (Pest and Stock Route Management) Act 2002*. This listing makes it illegal to introduce, supply or sell cat's claw creeper anywhere in Queensland.

In north-eastern New South Wales, cat's claw creeper has been given a high 'Threat Rating' (see Nagel 1995), and ranked as the most invasive environmental weed in the region due to its impact and difficulty of control (NCWAC 2001). Such prioritization, however, has not resulted in listings under the New South Wales *Noxious Weeds Act 1993* in the worst affected areas; rather the only declarations (11 in total) are all within the Sydney basin, where its density and impact is currently not as high.

Elsewhere in Australia, cat's claw creeper has been declared under the Western Australian *Plant Diseases Act 1974* as a quarantine weed, which prevents its importation into Western Australia (WA Agriculture 1999). No other state or territory has formally listed cat's claw creeper as noxious.

Weed management

In Australia, cat's claw creeper has been recognized as a candidate species for preventative control (Csurhes and Edwards 1998). However, it is extremely difficult to control, as the extensive underground root and tuber system is difficult to remove manually or to control with herbicides (Muyt 2001). Control can be achieved with continual perseverance, in part because cat's claw creeper has a limited seed bank and little seed dormancy (Vivian-Smith and Panetta 2004). For example, population densities of cat's claw creeper can be reduced by 95% after three years of control, with tuber density reduced to less than 1% of the pre-control density after five years of control (Achilles 2003). Furthermore, the recovery of host trees following such control can be vigorous (Stockard 1991). Such effective control can only be achieved with prolonged efforts, both manual and chemical, and a good plan of management (Achilles 2003). Changes to management regimes, however, can result in sudden increases in the abundance of cat's claw creeper. For example, the removal of stock in a dry rainforest remnant at Trenayr near Grafton, New South Wales, led to a sudden explosion of cat's claw creeper from a background species to one dominating approximately half of the 8.5 ha site in six years (Achilles 2003). Such explosions in the populations of cat's claw creeper highlight its potential as an environment weed.

Herbicides

The control of cat's claw creeper can be achieved with non-selective herbicides (Muyt 2001). However, effective control can be achieved only through targeted application that ensures both above and below ground parts of the plant are treated – although there is some debate about the need for spraying severed stems (see below) – and through intensive follow-up treatments, especially in well-established infestations (Muyt 2001). Herbicide application is most effective when the plants are actively growing; for cat's claw creeper that period is from late spring through to autumn, with the best time for foliar spray being when new growth is present (Swarbrick and Dreier 1990).

Stem injection trials revealed that commercially acceptable levels of control were only achieved seven months after the application of glyphosate – Weedmaster 360® (1:1 dilution at 5 mL per cut), and Tordon® TCH (20g kg^{-1} picloram, 1:1 at 5 mL), while Velpar® (hexazinone 250 g L^{-1}, undiluted at 3 mL) did not deliver acceptable control. In addition, the trial found that stem injection is only suitable for larger stemmed plants (i.e. with a diameter of >2 cm, Cook 2002).

Basal bark trials using herbicide mixed with diesel (1:30) and applied directly onto the bark at a height of 30 cm revealed a lag period between application and control. Very high levels of control were not achieved until 77 days after application of Garlon® 600 (triclopyr 600 g L^{-1}), commercially acceptable results were not observed until seven months after application of Access® (triclopyr 240 g L^{-1}), and very high levels not until 10 months, while for Starane® (fluroxypyr 262 g L^{-1}) moderate levels of control were not observed until 77 days and very high levels until seven months (Cook 2002). A subsequent trial using Garlon® 600 and Access® mixed with a higher rate of diesel (1:60) in which the herbicide was 'sprayed' at very low pressure (i.e. trickled) onto the bark rather than painted on found that commercially acceptable results were achieved with Garlon® 600 and only moderately acceptable results with Access® after 40 days (Cook 2002). Based on the initial trial the effectiveness of Access® in this trial may have been higher if a greater sampling interval had been used (i.e. seven or 10 months, rather than 44 days). Alternatively, scraping the bark and painting glyphosate (1:1.5) to the damaged bark has resulted in effective control of cat's claw creeper (BSRLG 2002). Due to the growth habit of cat's claw creeper (i.e. multiple stems growing up a host plant) care should be taken with using basal bark application to ensure the host stem is not treated.

Cut and paint trials found that stems cut through within 15 cm of the ground and the root end treated immediately (i.e. within 15 seconds) with either glyphosate or amitrol-T (amitrol plus ammonium thiocyanate) undiluted were effective. However, the more quickly herbicide can be applied the more effective the control of the roots and tubers (Armstrong 1992, Stockard 1993, 2001, Galbraith 1994, McClymont 1996). Additional trials also recommend the use of Tordon DS® (100 g picloram and 200 g triclopyr, 1:20 dilution; Armstrong and Anderson 2002), triclopyr and clopyralid, while metsulfuron-methyl appeared to have little impact after three months (Swarbrick and Breier 1990). Stems with a diameter of >1 cm should be painted immediately, while smaller stems need to have their bark stripped on one side for 20 cm to increase the surface area before painting with herbicide (Floyd 1989). The original permit for the use of glyphosate to control cat's claw creeper recommended a 1:12 dilution for cut stump control (NRA 2001); such specific information was not included in the subsequent permit (APVMA 2004).

Foliar application trials found that glyphosate and triclopyr were effective in controlling cat's claw creeper. However, metsulfuron-methyl and clopyralid appeared to have little impact after three (Swarbrick and Breier 1990) and 13 months (Sparshott 1993). Users have also observed successful control of cat's claw creeper using glyphosate (diluted at 1:100, 1:50) mixed with a surfactant such as codacide oil (McClymont 1998). Other surfactants have also given positive results, including Pulse and household detergent (at 4–5 drops L^{-1}) (Achilles 2003). It may take 1–2 months before the effects of foliar application are evident (Browne n.d.). Foliar application is most effective when cat's claw creeper forms scrambling vegetative mats along the ground (McClymont 1996). The original permit for the use of glyphosate to control cat's claw creeper recommended a 1:100 dilution for foliar application (NRA 2001); such specific information was not included in the subsequent permit (APVMA 2004). In riparian areas cat's claw creeper has been controlled through foliar application of Weedmaster 360® (glyphosate 360 g L^{-1}, Anon. n.d.).

Foliar application can also be used to control regrowth and seedlings using Kamba 500® (dicamba 500 g L^{-1}, 1:250 dilution; Armstrong and Anderson 2002), while clopyralid (at 0.9%) is recommended only for seedlings (Sparshott 1993). In addition, regrowth and suckers from tubers can be treated with glyphosate (1:100 plus 2 mL of LI700 (non-ionic surfactant and pH adjuster acidifier)) or glyphosate mixed with metsulfuron methyl (1.5 g 10 L^{-1} plus Agral 2 mL L^{-1}, BSRLG 2002), or Weedmaster 360® (glyphosate 360 g L^{-1}, 1:100; Anon. n.d.). Treatment of regrowth and seedlings should be undertaken 3–6 months after the initial control and thereafter several times a year in order to achieve long-term control (Achilles 2003).

As foliar application is difficult on climbing stems, one recommendation is to cut the stems about 1.5 m from the ground and then pull the vines away from the host tree, bundle and tie them up with a flexible section of vine, and spray with Roundup® (undiluted) immediately after recutting the bundled vines (Stockard 1993); ideally this should be done prior to flowering (Swarbrick and Dreier 1990). Similar recommendations have been made but with glyphosate (1:100) mixed with LI700 (see Achilles 2003). Thin vines are best treated using this technique (Muyt 2001). Alternatively, aerial stems can be treated by placing the cut ends through holes in the lids of tiny plastic bottles or 35 mm film canisters filled with undiluted glyphosate 360, with effective control observed within seven days (E. Surman personal communication). However, some authors suggest that cut stems do not need to be treated and can be left in the canopy to die (see other treatments below).

Recently trials were undertaken with Vigilant® (5% picloram) on the control of cat's claw creeper using several application methods, which suggested that excellent control can be achieved with cut and paint, while results from stem injection and basal bark application are still pending (Macspred 2006).

Biological control

The biological control program for cat's claw creeper was started in South Africa in 1996 and has identified nine potential agents to date. The first agent to be released (in March 1999) was the leaf-feeding gold-spotted tortoise beetle (*Charidotis auroguttata* Boheman), near Grootvadersbosch in South Africa. It is a very promising agent, as both the larvae and adult beetles feed on the leaves, resulting in skeletonization (Sparks 1999b, Williams 2000). In high numbers these beetles cause the leaves to drop off and the shoot tips to die back (Williams n.d., Sparks 2001).

In 2001 initial host-specificity testing began in Australia on the gold-spotted tortoise beetle (Dhileepan *et al*. 2005). No-choice tests showed that adult beetles fed and ovipositioned on cat's claw creeper. Very few eggs were oviposited on non-target plant species, none of which completed larval development into adults, with the exception of a few individuals (6.7%) on *Myoporum boninense* subsp. *australe* Chinnock. Choice tests, however, revealed no evidence of oviposition or larval development on *M. boninense* subsp. *australe*, supporting host-specificity (Dhileepan and Donnelly 2002), but the agent was not approved for release due to its non-target feeding on *Myoporum* (Dhileepan *et al*. 2005).

Four other insects are being examined in South Africa: a leaf-mining jewel beetle (cf. *Brachys* sp.), a leaf-tying pyralid moth (*Hypocosmia pyrochroma* Jones) and the leaf-sucking bugs (*Carvalhotingis visenda* (Drake & Hambleton) and *C. hollandi* (Drake), ARC-PPRI n.d.). An application is being sought to release the leaf-tying pyralid moth in Australia (Snow *et al*. 2006). The leaf-sucking bug, *C. visenda* has been recently imported into quarantine in Australia and host specificity testing has shown high specificity (Treviño *et al*. 2006).

Other treatments

Hand weeding and stem removal The removal of plants by hand is not practical, with the exception of very small plants in small patches (McClymont 1996, Muyt 2001). Once plants are established, the densely branched tuberous root system makes removal extremely difficult and ineffective, as the tubers tend to break off the roots when plants are dug out of the ground. This is problematic as each tuber can develop into a new plant or the roots left behind can resprout (Stockard 2001), and thus all tubers and roots need to be removed. Not only is removal labour intensive, but it can result in extreme soil disturbance that can damage the roots of other plants (McClymont 1996, Muyt 2001).

Cutting stems may lessen the impact of cat's claw creeper on host plants. If the vines are not too large they can be left in the host canopy, but if they are large they should be removed to protect the host from further damage due to their weight (McClymont 1996). The removal of stems within the canopy of host trees can be dangerous as cat's claw creeper can kill off host branches and pulling down dead or recently cut stems could bring down large amounts of plant material, both vine and host. Appropriate safety precautions (including the use of protective equipment) should be undertaken and protocols followed before working in heavily infested areas, as large unstable dead or dying trees and branches present a serious risk to workers. While cutting stems and leaving them in the canopy of host trees can be effective in killing the stems (R. Joseph personal communication), it does not stop the plant from regenerating from its roots and tubers, with new stems present within 5–6 weeks after cutting (Browne n.d.). Regrowth can have greater rates of attachment than the stems of uncut plants (Anon. 2004b). Removal of cut stems from the host trunk to several metres high can help in the detection and treatment of regrowth (Floyd 1989).

Grazing Cattle and sheep can be used to control cat's claw creeper in areas where it grows along the ground, as the leaves and young stems are palatable (Achilles 2003, Browne n.d.). Furthermore, competition from dense swards of grass can eliminate cat's claw creeper (Francis n.d.b). However, grazing is of limited value in controlling cat's claw creeper when it grows vertically above browsing height. As cat's claw creeper is mainly an environmental weed, grazing is not an option in many areas such as conservation reserves.

Fire There have been no studies on the effects of fire on cat's claw creeper. However, observational data suggest that cat's claw creeper can recover following wildfire. For example, in the Ewingar area of the Upper Clarence, cat's claw creeper was observed to rapidly produce new shoots from the root-tubers soon after a wildfire event (T. Moody personal communication). Such observations warrant further examination, as well as suggest that fire may not be effective in the management of cat's claw creeper.

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