# Boneseed and bitou bush in Western Australia: a tale of two *Chrysanthemoides*

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**Summary** Boneseed and bitou bush are present in Western Australia (WA) and subject to eradication, however prospects for success are quite divergent. Boneseed (*Chrysanthemoides monilifera monilifera* (L.) T.Norl.) has been present since at least 1950. Initial control efforts commenced in the late 1980s after the weed was discovered at several wheatbelt towns and in the Perth hills. Targeted control commenced in 2006 with the appointment of a national *Chrysanthemoides* co–ordinator, which led to the identification of 42 infestation locations. There is no doubt subsequent control efforts have helped reduce abundance and spread. However, on numerous occasions these efforts have regressed due to insufficient and short–term funding, breaks in management that allowed the seedbank to be refreshed, or not completing adequate delimitation. Boneseed is now known at 47 locations, and our review of past management efforts has established a current baseline and management plan that will deliver localised extirpation with an eventual goal for state–wide eradication.

The situation with bitou bush (*Chrysanthemoides monilifera rotundata* (DC.) T.Norl.) is a complete contrast. When bitou bush was first discovered at the industrial port of Kwinana in 2012, a systematic delimitation survey was undertaken. This initial survey found over 1,200 plants and seedlings over ca. 2.5 km$^2$, but a greater surveillance buffer area was added to the invasion footprint to achieve local delimitation. Subsequently the delimitation and buffer areas have been surveyed annually with new plants found yearly since. As of 2022 the seedbank is likely depleted, suggesting local eradication is feasible. Prospects for successful eradication of both species are at a point where management needs are critical, but the continuity of sufficient resources to deliver this outcome is uncertain. We discuss the remaining challenges for eradication of these WoNS species, the strategy to find the last plants and the data–driven approach that will enable future survey effort to deliver greater efficiency of resources without compromising effectiveness.

**Keywords** *Chrysanthemoides*, containment, delimitation, eradication, surveys, Western Australia.

## INTRODUCTION

*Chrysanthemoides monilifera* is a South African plant with at least six subspecies (Norlindh 1943) of which two are established in Australia: boneseed and bitou bush. The taxonomic groupings by subspecies have been supported by molecular genetics studies (Barker *et al.* 2009). Consequently, we treat the two subspecies as separate taxonomic entities.

Both boneseed and bitou bush are Weeds of National Significance (WoNS) in Australia (Thorp and Lynch 2000). Currently, under WA legislation (the *Biosecurity and Agriculture Management Act 2007*; Government of Western Australia 2007), *C. m. rotundata* (bitou bush) has been declared as category C1 (plants which should be excluded from part or all of WA), whereas *C. m. monilifera* (boneseed) is in category C2 (plants which should be eradicated from part or all of WA).

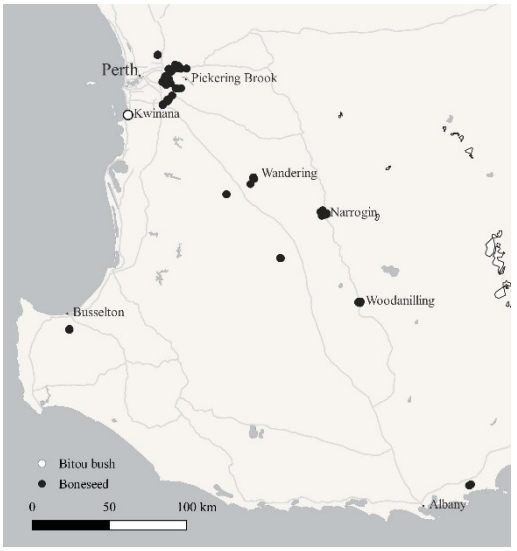
Despite this legislation, both taxa have naturalised in WA. In this paper we compare and contrast the outcomes of past management for *Chrysanthemoides* in WA and assess the feasibility of eradication as an end goal for both species.

## BONESEED MANAGEMENT

Boneseed has been present in WA for at least 75 years, 50 years longer than bitou bush (1 site, inferred to have started 1995). Consequently, it is far more widespread, covering 47 locations as of 2022, which are best described as comprising 89 sites (*cf* populations) because the management approach is different. The weed is mostly found around regional WA townships and residential gardens in the Perth Hills (Figure 1), with populations relatively small in extent (<50 m$^2$ up to 10 ha). Targeted control commenced in 2006 with the appointment of a National Boneseed Coordinator who profiled the distribution, extents and produced the WA Boneseed Eradication Strategy (Cherry 2010). Since then, boneseed management has been mostly resourced with short–term (not necessarily consecutive) NRM grants in urban areas and in an *ad hoc* way by Department of Primary Industries and Development (DPRID) biosecurity staff in regional areas. Sites were visited most years, but missed years have occurred due to breaks in funding and staff changes,

resulting in refreshed seedbanks and extents not being fully translated.

**Figure 1.** Distribution in 2022 of boneseed and bitou bush in Western Australia.




In 2020, the authors commenced a data aggregation project to generate a complete understanding of the extent of boneseed in WA, along with management and other influential events (e.g., fire) that have occurred at each site. We extracted data from diverse sources; including individual GPSs of people who have made surveys, government databases across multiple agencies and by interviewing landholders and retired staff. This process resulted in a database of over 2,000 records of weed removal, with detailed information on the demography of 700 records. From this synthesis, a historical timeline was developed for each site together with a future projection of extirpation likelihood, based on the last known fruiting event and assuming effective annual control is deployed (Figure 2). We also produced a risk heat map for each site, using locations where seedlings are recurrent suggesting a live seedbank.

Based on this aggregation and attending all the populations as part of this work, including 7 past extirpated sites, we estimate that it will take a minimum of 2,100 hours of on–site surveillance over the next 16 years (starting from at least 212 hours in 2022, decreasing to 64 hours in 2036) to achieve full extirpation for the 47 locations across the state. Some sites require delimitation before extirpation can declared. This estimate is based on a cautiously predicted viable seedbank of up to 15 years (anecdotal evidence suggests 10 years, L. McMillan pers. comm.), the effectiveness of existing control methods and a sustained management program. This duration may be reduced if methods to enhance the depletion of the soil seedbank, or drone–based detection of isolated plants are successfully developed; work that is currently underway.

Our baseline assessment reinforces that biocontrol is not a logical solution to pursue for boneseed in Western Australia while eradication remains feasible. However, we recommend the genetics of boneseed across Australia be examined in case other states were to restart their biocontrol development programs. With a single aggregated spatiotemporal database now available for all boneseed populations in Western Australia, we are now able to deploy a robust and realistic eradication program, but one that must remain informed by adaptive management.

## BITOU BUSH MANAGEMENT

The situation with bitou bush is a complete contrast to that of boneseed in WA. Bitou bush was discovered in the state in 2012 as an established population of some 1,700 plants in the coastal industrial area of Kwinana, south of Perth (Scott and Batchelor 2014). CSIRO, recognizing a unique opportunity to study a species at an early invasion phase, proposed to undertake a delimitation survey to realise the extent of the population and removed plants along the way. This initial survey found over 1,200 plants and seedlings over ca. 250 ha, but a greater surveillance buffer area was added to the invasion footprint to achieve local delimitation. The delimitation and buffer areas have been surveyed annually with new plants found every year since (Figure 3). Very few seedlings have been found since 2017 and none since 2020. Three large plants were found in the 2022 annual survey carried out between April–June, all within the delimitation area and well hidden amongst dense vegetation, one of which was only discovered by drone, demonstrating the bitou threat is not over.

The annual decline in bitou bush numbers with each annual survey was reported in Scott *et al.* (2019b). Between 2012 and 2018 we surveyed over 253 ha of land and removed 1,766 bitou bush plants. The seed bank was measured using soil cores and by 2018 the seed bank was undetectable with the standard sampling methods used. By 2022, 1,792 plants have been removed and we expect the bitou bush seedbank to be depleted, based on seed viability of 5–7 years (K. French, pers. comm.), suggesting successful extirpation is a near term possibility.

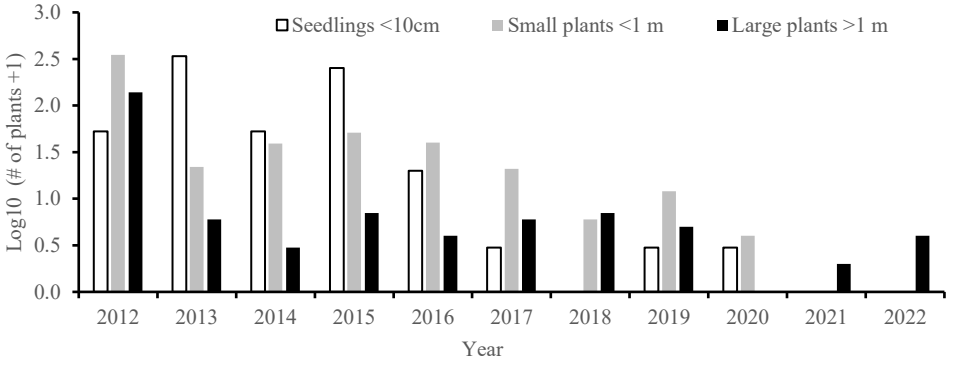
This targeted and systematic approach to annual surveying and confirming delimitation has been undertaken in a consistent and evidence–based way.

However, despite familiarity with the species and known hot–spot locations, large plants are still missed apparently obscured by vegetation and infrastructure in previous years. Extirpation is not expected until 2026, as the last possible fruiting event occurred in 2019.

Could extirpation have been achieved earlier for bitou bush in WA? Unfortunately, fire as a management tool (for stimulation of the seedbank and reduction of above ground biomass and seed) was unfeasible due to the close proximity of petrochemical plants and other industry. The program has been assisted over the survey period by a reduction in the risk footprint (and therefore survey area) due to an increasing cover of concrete and industrial development.

**Figure 2.** A past and planned future management timeline for boneseed control at sites near the town of Narrogin. Red line is current year (2022).


**Figure 3**. Log comparison of bitou bush plants and seedlings found at Kwinana between 2012 and 2022. Plant size categories refer to maximum crown diameter.




## DISCUSSION

Bitou bush can be considered effectively contained in WA while being annually surveyed. However, bitou bush is at the stage where the survey effort to find the last plants is at its greatest, while boneseed remains at risk of becoming unfeasible to eradicate if current surveys are suspended or infestations are not adequately delimited.

One of the main challenges for finding the last plants is their ability to meld in with other vegetation and not be seen over multiple years. In Scott *et al.* (2019a) we give the example of a pair of bitou bush plants growing under a clump of *Acacia* and not spotted until they were 3 m tall and in flower. Boneseed is equally challenging to detect during surveys but has the additional challenge of being distributed across residential properties, which have access challenges.

Positively, bitou bush is an obligate outcrossing taxon (Gross *et al.* 2017; Scott *et al.* 2019a). This means that isolated plants do not produce seeds until another individual germinates nearby and flowers (i.e., subject to allee effects due to pollination limitations). It is not known if boneseed is likewise

outcrossing. This fact needs to be determined as it has significant implications for boneseed management when population numbers become very low.

An important element of delimitation is understanding how re–invasion could occur. This means understanding the original invasion progress. Currently we are assessing three lines of evidence on the re ─ invasion issue; history, based on documented records of bitou bush, nuclear DNA genome variation, and chloroplast DNA genome variation.

Both boneseed and bitou bush are bird and rodent dispersed, but given the length of time they have been in WA, it is surprising they aren't more widely distributed. One possibility is the lack of suitable long–distance volant dispersers. Starlings (*Sturnus vulgaris* L.) for example, are absent in WA and parrots are effective seed predators. Bitou bush is also in a highly industrialised area, and while plants were often found under bird perches (fences and light posts) evidence of rodent feeding was observed with gnawed endocarps found in the soil cores, providing another seed control mechanism.

Research on seed bank longevity is underway (K. French pers comm) and its outcome is critical to predicting the length of both control programs. Schoeman *et al.* (2010) showed bitou seeds have reduced resilience compared to boneseed, and the two sub-species should be considered separately when designing effective control measures.

## CONCLUSION

We have adopted a data driven approach for improving control outcomes for both boneseed and bitou bush. Taking this adaptive management approach to delivering successful extirpation also provides useful motivation and feedback through the program via evidence of progress, even if small. Establishing the contribution of the seed bank to ongoing invasion risk was critical for the strategy adopted for bitou bush (Scott *et al.* 2019a). A similar data–driven approach for boneseed should enable future survey effort to deliver greater efficiency of resources without compromising effectiveness. Past management efforts have been effective at containing boneseed, as since Cherry (2010) only four addition sites have been found. Moreover, with effective future management 20 sites are likely to be extirpated within three years. Significant resources have been invested in removing boneseed across WA since 2006. Without a long–term management commitment, we predict that infestations will revert to their pre–2006 state within a decade. The value proposition of ongoing control thus appears a most attractive proposition, positioning WA to achieve eradication for two Weeds of National Significance.


## ACKNOWLEDGMENTS

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