

Informing eradication feasibility: ecological context and delimitation for boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) in Western Australia

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Supplementary Material

Table S1. Sites in Western Australia where evidence supports extirpation of boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*).

Location	LGA	Site	Rationale	Extirpation year	Year most recently inspected
Regional	Albany	Rae Rd and Francis Street	Properties developed, risk removed	2007	2021
Regional	Northampton	Nabawa	Herbarium record no evidence of naturalisation	1954	2021
Regional	Pingelly	Tutanning Nature Reserve	Herbarium record no evidence of naturalisation	1969	2021
Regional	Toodyay	Morangup	Herbarium record no evidence of naturalisation	1984	2021
Regional	Wyalkatchem	White Dam Reserve and Rubbish tip	Recorded in APB report and FIS dataset records	1994	2021
Urban	Applecross	Mt Pleasant	Herbarium record, property developed	1974	2021
Urban	Mundaring	John Forrest National Park, Hovea	Small infestation, intensive control 2007-2009, including topsoil removal and grubbing. Annual surveillance, burn in 2017. No evidence of infestation in the park and an active landcare group is monitoring the park	2009	2021

Table S2. Sites in Western Australia with a 'watch' status recommended for boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) as of December 2023.

Location	LGA	Population	Tenure	Site summary	Year fruiting last observed
Regional	Narrogin	Narrogin 8	Private	114 Doney St	2007
Regional	Narrogin	Narrogin 8	Private	116 Doney St	2007
Regional	Narrogin	Narrogin 8	Private	2 Pitt St	2009
Regional	Narrogin	Narrogin 8	Private	8 Touhy St	2007
Regional	Narrogin	Narrogin 8	Private	86 Kipling St	2007
Regional	Wandering	Wandering 2	Government	Moramocking Rd Gravel Pit	2006
Regional	Woodanilling	Woodanilling 1	Private	Great Southern Hwy	2006
Regional	Woodanilling	Woodanilling 3	Private	20-23 Carlton St	2006
Urban	Kalamunda	Gooseberry Hill	Private	Noel Rd	2007
Urban	Kalamunda	Gooseberry Hill	Private	Railway Rd	2007
Urban	Mundaring	Darlington 1	Government	Mount St	2009
Urban	Mundaring	Darlington 2	Private	Helena College	2008

Table S3. Regional sites in Western Australia recommended for an extirpation approach to management of boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) as of December 2023. *Surveillance effort is on site time only based on engaging experienced personnel, excluding logistics and travel to site.

LGA	Population	Vestiture	Site Summary	Year fruiting last observed	Predicted extirpation year	Years until extirpation	Estimated annual surveillance effort (hours)*
Albany	Manypeaks	Government	North road verge	2021	2037	14	3
Albany	Manypeaks	Government	South road verge	2020	2036	13	3
Albany	Manypeaks	Private	137	2021	2037	14	3
Albany	Manypeaks	Private	Waychincup Rd 275 Waychincup Rd	2021	2037	14	3
Boddington	Boddington	Government	Hotham River	2012	2028	5	3.75
Busselton	Vasse	Government	Creeklane	2020	2036	13	2.5
Busselton	Vasse	Government	Chugg Rd	2020	2036	13	2.5
Narrogin	Narrogin 1	Government	Narrogin High School	2021	2037	14	3.75
Narrogin	Narrogin 2	Government	Fleay Rd	2010	2026	3	1.25
Narrogin	Narrogin 3	Government	Fox Lair Arboretum	2008	2024	1	1.25
Narrogin	Narrogin 3	Government	Fox Lair Commonage	2008	2024	1	1.25
Narrogin	Narrogin 4	Government	Narrogin-Wandering Rd	2012	2028	5	1.25
Narrogin	Narrogin 5	Government	New Rubbish Tip	2012	2028	5	3.75
Narrogin	Narrogin 5	Government	Old Rubbish Tip	2014	2030	7	3.75
Narrogin	Narrogin 6	Government	Pioneer Dve	2022	2038	15	2.5
Narrogin	Narrogin 7	Government	Touhy Reserve	2012	2028	5	2.5
Narrogin	Narrogin 7	Government	Water Corp Earl St	2008	2024	1	1.25
Narrogin	Narrogin 7	Government	46-47 Fairway	2008	2024	1	1.25
Narrogin	Narrogin 7	Private	83 Felspar St	2012	2028	5	1.25
Wandering	Wandering 1	Government	Old Mill	2020	2036	13	1.25
Wandering	Wandering 1	Government	Primary School	2011	2027	4	1.25
Wandering	Wandering 1	Government	Caravan Park	2016	2032	9	2.5
Wandering	Wandering 1	Government	Gravel Pit	2021	2037	14	3.75
Wandering	Wandering 1	Government	Rubbish Tip	2020	2036	13	5
Wandering	Wandering 1	Government	Water Corp	2020	2036	13	5
Williams	Dardadine	Government	Old School site	2008	2024	1	2.5
Williams	Dardadine	Government	Dardadine South Road	2008	2024	1	2.5
Woodanilling	Woodanilling 2	Government	Shenton Rd	2020	2036	13	5
Woodanilling	Woodanilling 1	Government	Haddelton Rd	2010	2026	3	1.25
Woodanilling	Woodanilling 1	Government	Rubbish Tip	2022	2038	15	5
Woodanilling	Woodanilling 3	Private	3346 Robinson Rd	2021	2037	14	2.5
Woodanilling	Woodanilling 3	Private	4-6 Mouritz Rd	2021	2037	14	2.5
TOTAL							85.75

Table S4. Urban sites in Western Australia recommended for an extirpation approach to management of boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) as of December 2021.

LGA	Population	Tenure	Site Summary	Year fruiting last observed	Predicted extirpation year	Years until extirpation	Estimated annual surveillance effort (hours)*
Armadale	Armadale	Government	Bedforddale Hill Rd	2008	2024	1	2.5
Armadale	Armadale	Private	117 Burrows-147 Albany Hwy	2021	2037	14	5
Armadale	Armadale	Private	144-156 Albany Hwy	2008	2024	1	2.5
Armadale	Armadale	Private	93-115 Burrows Retreat	2009	2025	2	2.5
Armadale	Roleystone 1	Government	60 Peet Rd Watertank	2011	2027	4	2.5
Armadale	Roleystone 2	Government	Springdale Tip	2009	2025	2	2.5
Kalamunda	Gooseberry Hill	Private	Gooseberry Hill Rd	2013	2029	6	2.5
Kalamunda	Gooseberry Hill	Private	Landor Rd	2021	2037	14	2.5
Kalamunda	Lesmurdie 1	Private	48 Recreation Rd	2008	2024	1	1.25
Kalamunda	Lesmurdie 1	Private	180-187 Grove Rd	2010	2026	3	1.25
Kalamunda	Lesmurdie 1	Private	Parry House	2016	2032	9	2.5
Kalamunda	Lesmurdie 2	Government	Falls Road Primary	2010	2026	3	1.25
Kalamunda	Lesmurdie 3	Private	25 Gilchrist Rd	2009	2025	2	1.25
Kalamunda	Lesmurdie 4	Government	Alan Anderson Reserve	2014	2030	7	1.25
Kalamunda	Kalamunda 1	Private	2 East Tce	2008	2024	1	1.25
Kalamunda	Kalamunda 1	Private	3-12 Roach Rd	2008	2024	1	2.5
Kalamunda	Kalamunda 1	Private	41-47 Heath Rd	2011	2027	4	1.25
Kalamunda	Kalamunda 1	Private	Croxton Rd	2009	2025	2	1.25
Kalamunda	Kalamunda 2	Government	MRP near Brine Rd	2020	2036	13	2.5
Kalamunda	Kalamunda 2	Government	MRP near Moran Rd	2008	2024	1	2.5
Kalamunda	Pickering Brook	Government	Carinyah Rd	2022	2038	15	5
Kalamunda	Pickering Brook	Private	121 Merrivale Rd	2009	2025	2	1.25
Mundaring	Darlington 1	Government	Towerhill Crt	2010	2026	3	2.5
Mundaring	Darlington 1	Government	Camfield/Pitterson Rd	2011	2027	4	2.5
Mundaring	Darlington 2	Government	Leithdale Rd	2021	2037	14	2.5
Mundaring	Darlington 2	Private	10-100 Ryecroft Rd	2020	2036	13	2.5
Mundaring	Darlington 2	Private	175-245 Ryecroft Rd	2020	2036	13	2.5
Mundaring	Darlington 2	Government	Hillcrest Dr	2011	2027	4	2.5
Mundaring	Mahogany creek	Private	2145 Jacoby St	2016	2032	9	1.25
Mundaring	Mahogany creek	Private	6260 GE Hwy	2016	2032	9	1.25
Mundaring	Parkerville 1	Private	Seaborne St	2008	2024	1	1.25
Mundaring	Parkerville 2	Private	Brooking Rd	2021	2037	14	5
Mundaring	Sawyers Valley	Private	Forrest St	2008	2024	1	2.5
Swan	Henley Brook	Private	130 Rookwood St	2021	2037	14	2.5
Swan	Henley Brook	Private	131 Rookwood St	2008	2024	1	2.5
Swan	Henley Brook	Private	63 Saunders St	2012	2028	5	2.5
TOTAL							82.5

Table S5. Urban sites in Western Australia where an extirpation of boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) is unlikely in the short term, and containment is first required while delimitation is achieved. *Extirpation could be still a reality if delimitation can be performed in the near-term

LGA	Population	Tenure	Site Summary	Last fruiting observation	Predicted extirpation year	Years until extirpation*	Estimated Annual Surveillance Effort (hours)
Armadale	Armadale	Government	Neerigan Brook	2020	2036	13	7.5
Armadale	Wungong	Government	Wungong Regional Park	2021	2037	14	15
Armadale	Roleystone 1	Government	Beales Ct Culvert	2021	2037	14	5
Armadale	Roleystone 1	Private	33 Mackie Rd	2021	2037	14	1.25
Armadale	Roleystone 1	Private	39-51 Mackie Rd	2021	2037	14	5
Armadale	Roleystone 1	Private	455-469 Brookton Hwy	2020	2036	13	2.5
Armadale	Roleystone 1	Private	516-538 Brookton Hwy	2016	2032	9	2.5
Kalamunda	Lesmurdie 5	Government	Lower Lesmurdie Falls	2017	2033	10	5
Swan	Henley Brook	Government	77 Saunders St	2021	2037	14	5
Total							48.75

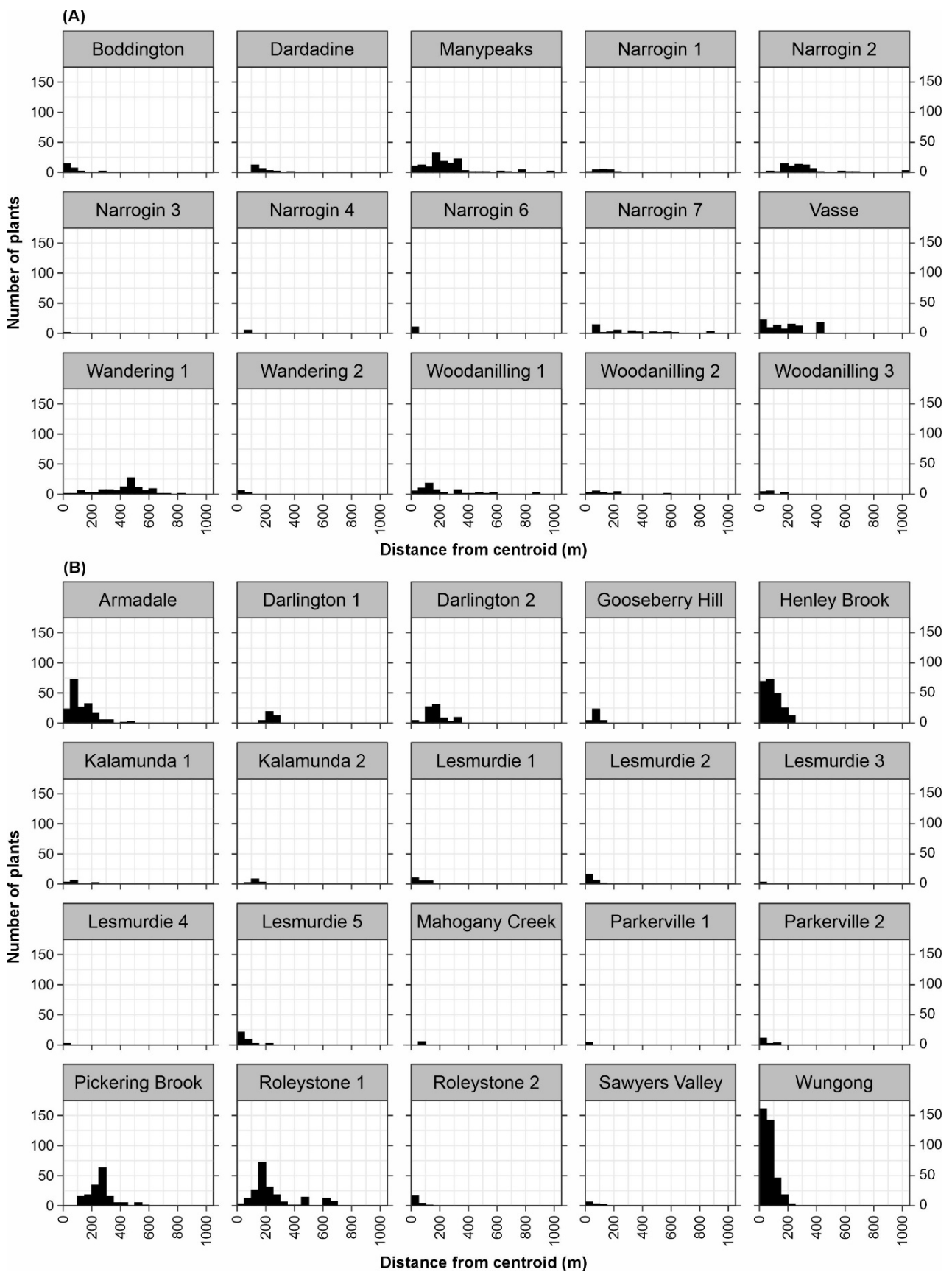


Figure S1. Distance of individual boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) plants to mean centroid for each population in regional (A) and urban (B) locations.

Supplementary Appendix S1

Databases with information on boneseed sites

At least six organisations have maintained their own database of boneseed sites and historical management activities in Western Australia (WA). Other organisations and individuals have been able to provide an oral history of on ground works and events at some sites.

Seven databases were maintained before and during the 2021 survey.

1. WA Herbarium (1948-2007) and WA Boneseed Eradication Strategy. Cherry (2010) accessed all boneseed specimens in the WA Herbarium in 2006 and formed a dataset of populations based on the collection details, site surveys and expert knowledge of local APB staff at the time. From this synthesis, Cherry (2010) determined there were 42 discrete sites in WA where boneseed has been found, six of which were presumed extirpated.
2. Annual reports of the Western Australian Agriculture Protection Board (1983-1996). Boneseed was first mentioned in a 1983 annual report and in most years until 1996, when reporting of P5 weeds in the annual report ceased. Boneseed was generally mentioned in either paragraph text or in a table with the number of sites, along with area or number of sites controlled.
3. Between 1986 and 2018, the Department of Primary Industries and Regional Development (DPIRD) maintained a database, the Field Inspection System (FIS), that recorded populations of declared pest species against agricultural and other property parcels in Western Australia. FIS is not a publicly available dataset. In this system boneseed observations were attached to polygon features. Relevant fields were Property ID, Date, Infestation size (light, medium or heavy) and OBS (compliance, surveillance, audit). The Property ID field was indexed in a publicly available DPIRD spatial layer called Client Property Event System (<https://catalogue.data.wa.gov.au/dataset/client-property-event-system-properties>). Information from this database was used to compile plant demography at each site. Information on boneseed mentioned in APB annual reports was included in FIS.
4. WA Roadside Conservation Committee database. The WA Roadside Conservation Committee database catalogues records of flora found in roadsides in Western Australia (<https://catalogue.data.wa.gov.au/dataset/roadside-conservation-committee-rcc-status-map-dpaw-042>). As boneseed is often found along road verges, this dataset was considered a potential source of potential new locations. The publicly available dataset was last updated in 2017. Boneseed was recorded twice in the shire of Dandaragan in this database.
5. Perth NRM (2009-2018). Luke McMillan at Perth NRM was the WA State Boneseed Coordinator between 2009-2018 and in this role, he arranged the removal of large quantities of boneseed at several locations in the Perth Hills area. He also undertook annual surveillance and control of sites each year until 2018 and assisted with surveillance in regional areas. Records from his surveillance database, field GPS and personal knowledge were used to populate many of the points in the aggregated database and compile plant demography at each site.
6. DPIRD IQC records (2019-2021). DPIRD have adopted a point location approach to pest plants on properties since 2019, using ESRI Field Collector. The Inspection Quarantine Compliance (IQC) database is very recent and includes observations of individuals between 2019-2021. It allows for better recording of absence data at an individual level.
7. South East Regional Centre for Urban Landcare, SERCUL (2020-2021). SERCUL received a grant to manage Perth infestations of boneseed between 2020-2021. They coordinated the annual surveillance and management as part of delivering this grant. Data from their field GPS was

captured in the form of waypoints, describing maturity and number of individuals and whether seed had dropped if mature plants were found.

Lost or unretrieved data

The City of Albany, Shire of Kalamunda and Shire of Mundaring Landcare staff have all been involved in boneseed removal in Western Australia and may have data on old devices or computers within each organisation. Staff turnover and retirements have made these data difficult to track down. While it was not possible to include such data in this synthesis, there would be merit in continuing to pursue these sources as a part of future management programs. Previous DPIRD staff now long retired evidently also have recorded boneseed locations which were kept offline in *ad hoc* databases. Furthermore, DPIRD FIS data between 2015-2018 was requested but not provided, however functional summaries of these data were interpreted with clarification from DPIRD staff.

References

Cherry H (2010) Western Australia Boneseed Eradication Strategy. Unpublished Report. 23 p

Supplementary Appendix S2

Case Study 1: Manypeaks - City of Albany, WA

In 2007 Hillary Cherry described a previously unrecorded infestation of at least 100 mature boneseed and 500 seedlings along a 2 km stretch of Waychinicup Rd in Manypeaks, WA. Boneseed was recorded in the remnant bushland on two private landholdings, 137 and 275 Waychinicup Rd, and on both the north and south road verges (making four sites). In 2021 large plants were found in the house garden of 275 Waychinicup Rd, which were missed in the 2006 - 2007 surveys. In addition, the Manypeaks boneseed population is 160 km from the nearest active infestation in Woodanilling making garden planting the most likely pathway of invasion. Currently the Manypeaks infestation is contained, but an ongoing risk to nearby Mt Manypeaks Nature Reserve until extirpation is achieved.

Site description

The road verges in this section of Waychinicup Rd are 5-10 m deep, thickly vegetated and boneseed was mostly found at the base of trees. 137 Waychinicup Rd has been a blue gum (*Eucalyptus globulus*) plantation from at least 2000 and the main agriculture on properties 154, 275 and 332 Waychinicup Rd is sheep/cattle grazing. The boneseed in remnant bushland areas of 275 Waychinicup Rd is fenced off from the main farm, and the bushland to the east of the homestead is protected under a conservation covenant and subject to winter water inundation.

Management history

The boneseed plants found in 2006-2007 were removed by the City of Albany in September 2007. It is not known if follow up surveillance occurred between 2008-2010. The next inspection was in 2011 by Perth NRM and jointly (but not necessarily co-ordinated) between City of Albany and DPIRD 2012 - 2021. Information about location of plants was compiled from Perth NRM and DPIRD data. The Manypeaks site has had annual surveillance since 2011, but missed plants and the lack of a central, accessible data repository to detail the extent of the infestation has hampered progress toward extirpation.

Delimitation

In September 2021, DPIRD and CSIRO undertook a delimitation survey of the Manypeaks site, covering the known extent plus a buffer area of 500 m (Figure S2). No new plants were found beyond the known extent. However, the shelter belts on 154 Waychinicup Rd still require inspection as the paddocks were inundated with water at the time and therefore not accessible for surveying. In addition, the vegetation at Manypeaks is quite dense, making it difficult to locate boneseed amongst other yellow flowering vegetation. While the total delimitation area for Manypeaks was 250 ha, the area at risk from boneseed infestation is far smaller (i.e., grass paddocks and tree plantations were excluded), covering approximately 22 ha of verge and remnant vegetation.

Future management

With annual surveillance (two people for one day), but without measures to stimulate the seedbank extirpation is achievable but not expected until 2035 based on current methods and knowledge on seed longevity (Figure S3). The City of Albany have designed a program of prescribed burns covering the north and south road verges for autumn of 2023, which could stimulate the seedbank to germinate, improving the likelihood of containment and reducing the scale of surveillance. The City of Albany have also suggested 'mulching to a depth of 0.5 m' as an outcome for the house garden of 275 Waychinicup Rd. Such an approach would simulate deep burial, which has been successful for the suppression of *Acacia longifolia* germination elsewhere in the City. They will discuss this possibility with the property owner.



Figure S2. Delimitation survey area of the boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) extent at Manypeaks. Background image: Google Maps (2021).

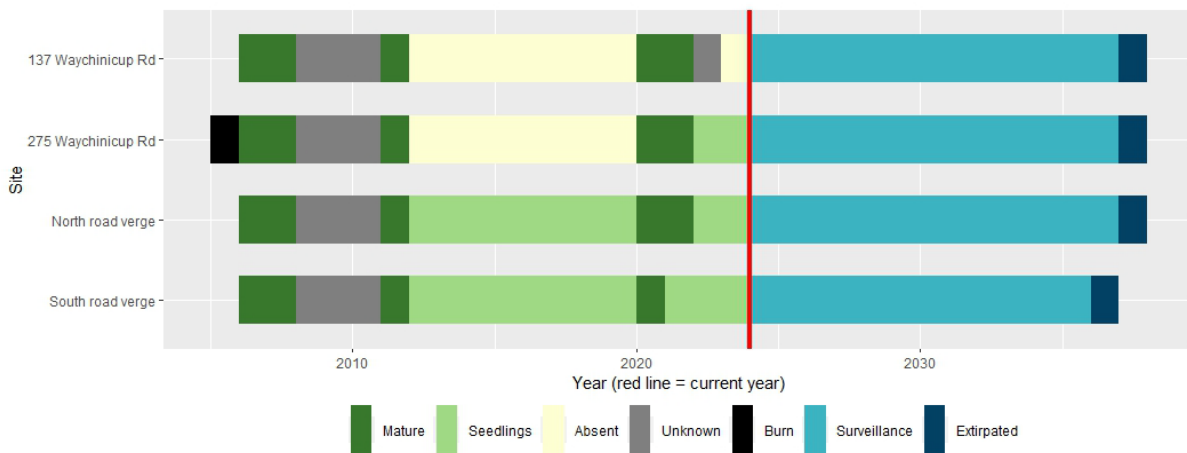


Figure S3. Management timeline for the Manypeaks boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) location.

Case Study 2: Vasse - City of Busselton, WA

First recorded in the WA Herbarium in 1993 by Greg Keighery, the location was noted as “Crump Rd, base Whicher Range, 15 km SSE Busselton”. As there is no Crump Rd near Busselton or Whicher Range, the authors contacted the collector to clarify the location. We were able to confirm that it was at Chugg Rd, adjacent to the former Department of Agriculture Research Station in Vasse. Recorded as site 34 (Cherry, 2010b), the nearest other infestation of boneseed is in Boddington, 150 km away.

DPIRD are the property owners of the Former Vasse Research station, but the associated dairy at 4711 Jalbarragup Rd has been leased-out to private tenants since 2012. The buildings of the old Vasse Research station were recently leased to DBCA Blackwood Region Fire Unit. The road verge on Chugg Rd is the responsibility of City of Busselton.

Site description

Vasse is described as one population over two sites. Boneseed is found along both sides of Chugg Rd reserve, up to 450 m from the intersection with Jalbarragup Rd and along the banks of a fenced creek line extending from the bridge on Chugg Rd up to 650 m to the north (Figure S4). The understory of the creek line and Rd edge is quite degraded, with kikuyu (*Cenchrus clandestinus*) and annual grasses in the understory below eucalypts. Cattle are often let inside the fenced creek area to keep the grass under control.

Management history

The earliest control efforts against boneseed were undertaken by DPIRD staff in 2001 on Chugg Rd. Control (described as compliance in the dataset) is listed against every year between 2006-2014, and while plant size is not specifically mentioned, they were probably mostly seedlings since surveillance was consistent. A small area around the Chugg Rd bridge was burnt in August 2011 that resulted in up to 78 seedlings over a 0.25m² 9 weeks later (B. Rayner, ex-DPIRD pers. comm.).

The earliest control effort against boneseed in the creek line was in 2006. Control was applied between 2006-2009 then 2011-2014. No inspection occurred in 2010. No plants were recorded in any dataset between 2015-2018, but large plants were found along both Chugg Rd and the creek line in 2019, effectively replenishing the soil seedbank with fresh seed (Figure S4). The creek line area has been fenced off from the main farm since at least 1996, but it is not known for how many years cattle have been able to graze in the area.

Delimitation

In September 2021, DPIRD and CSIRO undertook a delimitation survey of the Vasse infestation (Figure S4), covering the known extent plus a buffer area of 500 m, based on a likely realised bird dispersal distance. No new plants were found beyond the known extent.

Future management

Without measures to stimulate the seedbank, and with continued annual surveillance, extirpation is not expected until 2035 (Figure S5) and annual surveillance covering the known extent can be achieved with one person and approximately five hours each year. Enhanced management in the form of a controlled burn has been discussed with DPIRD and the City of Busselton and may be possible with the assistance from DBCA due to the risk this infestation poses to nearby Whicher Range.



Figure S4. Delimitation survey area of the boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) extent along Chugg Rd in Vasse. Background image: Google (2021).

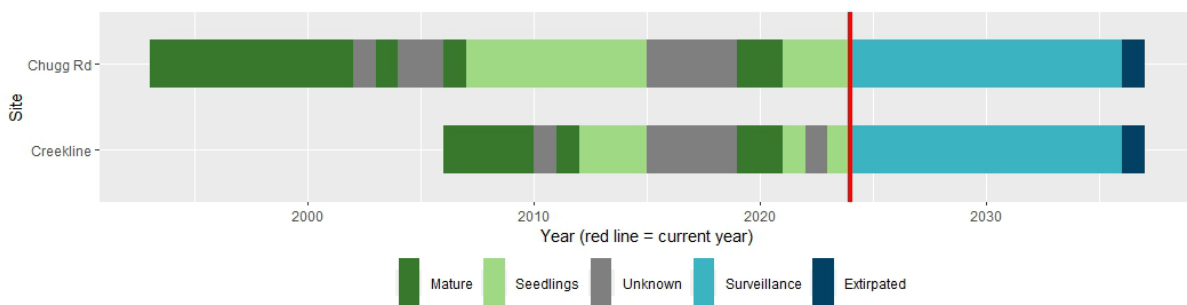


Figure S5. Management timeline for the Vasse boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*) location.