Orange hawkweed in Tasmania
Status Report

Executive summary

Orange hawkweed (OHW) *Pilosella aurantiaca subsp. aurantiaca* is a declared weed under the Tasmanian *Weed Management Act 1999.* It is an aggressive invasive species which poses a threat to native alpine and sub-alpine vegetation in Tasmania (and is also found in alpine areas in Victoria and NSW). OHW is currently limited in its distribution in Tasmania, with known populations on the outskirts of Hobart, the Central Highlands and previous records in Circular Head, Meander Valley, Maydena and Kingborough municipalities. If allowed to spread, OHW could be highly detrimental to Tasmania's agricultural and environmental values, including areas such as the Tasmanian Wilderness World Heritage Area.

NRM South was commissioned by Biosecurity Tasmania to:

- Identify key stakeholders involved in orange hawkweed (OHW) management
- Re-instigate an OHW Network of key landowners and managers
- Explore alternative funding options such as from the Weed Action Fund to implement actions as agreed by the network
- Delimiting surveillance of potential new sites through a facilitated mapping workshop
- Ground-truthing of mapped delimited surveillance sites
- Increased awareness amongst landholders and land managers in areas at risk of infestations
- Re-assessment of known infestations, particularly for Fern Tree
- Coordinated treatment of agreed sites
- Status report

Once the work commenced, the key deliverables evolved into:

- Identify key stakeholders involved with OHW
- Re-establish the OHW Network
- Map the current known distribution and historical spread of OHW
- Examine the utility of modelling to identify potential new infestations
- Examine the efficacy of using dogs to detect OHW
- Produce a Status Report, including recommendations for future action.

This document is the Status Report and details the outcomes relating to that listed above.

The OHW Network was re-established in early 2019 and included key stakeholders managing the weed. The Network met five times between February and June 2019. Input from the Network and data from the Tasmanian Natural Values Atlas was used to map the currently known distribution of OHW.

CSIRO was commissioned to develop a model for OHW in Tasmania, based on several known incursions in the Central Highlands. The model used the dispersal mechanisms of wind, water and roads. It was preliminary but indicated that wind, road and water-based dispersal

was limited. The model has potential, but further work is required, including additional iterations, more field data and trials.

Another focus of the project was assessing the contribution detector dogs could make to identifying OHW. Funds were provided for the training of the detector dog "Fonz", who had been previously trained on serrated tussock. Once the five days of training for OHW was completed, he underwent further training and trials in the field at Fern Tree and the Central Highlands. These trials indicated a great deal of potential to detect OHW, particularly outlying patches, and could be used to complement other forms of monitoring.

The report also documents the various treatment strategies for OHW and provides a series of recommendations to achieve the objective of eradication of OHW in Tasmania.

Contents

1. Introduction

The purpose of this Status Report is to collate all currently known information about orange hawkweed (OHW) in Tasmania and to develop recommendations for its control and potential longer-term eradication. The Report has been developed by NRM South for Biosecurity Tasmania and is based on extensive input from the re-formed OHW Network. The Report aims to:

- Identify all relevant stakeholders/landowners that are managing OHW
- Document the known distribution of OHW and its movement over time
- Model the potential occurrence of OHW beyond known areas
- Investigate the possibility of using detector dogs for OHW
- Document treatment strategies, including evaluating which are the most effective
- Collate current resources
- Provide recommendations.

Species description

OHW *Pilosella aurantiaca subsp. aurantiaca* is a declared weed under the Tasmanian *Weed Management Act 1999.* It is an aggressive invasive species which poses a threat to native alpine and sub-alpine vegetation in Tasmania (and the highland areas on mainland Australia, including Kosciuszko National Park in New South Wales and Falls Creek in the Victorian high country). On mainland Australia, it is believed that OHW was introduced at the Snowy Mountain Hydro Scheme when construction began in 1949, and then escaped following the 2002 bushfires (Terret 2013). It was found in the Victorian high country in 1999 and in New South Wales in 2003 (Caldwell and Wright 2011).

There is some conjecture about how it was brought into Tasmania, with theories ranging from it having been imported (possibly as seed) and planted in the 1920s by immigrants working on Hydro schemes at villages including Shannon and Butlers Gorge and possibly Miena and Wayatinah (D. Graddon, Hydro Tasmania pers. comm.). It has also been speculated that OHW around Haddens Bay at Miena (the Thiessan Crescent area) may have been introduced at Hydro houses at Haddens Bay (S. Leighton, Department of State Growth pers. comm.). It is also possible that hawkweeds were deliberately introduced in the late 1800's by "Preservation Societies", as they were into New Zealand. It is thought that OHW was introduced into gardens of houses built in the 1950s in Fern Tree, on the outskirts of Hobart, where it was first identified some time before 1963.

OHW has the potential to impact natural and agricultural values and is hence regarded nationally as an Environmental Alert and Agricultural sleeper weed (Department of the Environment and Energy 2019). It can form dense mats, with resultant impacts on biodiversity and productivity. Experiences in New Zealand and the highlands of Victoria and New South Wales demonstrate the potential for OHW to outcompete native alpine vegetation, producing carpets of dense infestations (Natural Heritage Trust 2003). It is currently regarded as an eradicable 'sleeper' weed because it is in the early stages of establishment, but if left uncontrolled has the potential to cost $48 million in agricultural losses across Australia (Brinkley and Bomford 2002). It also has the potential to impact

cultural heritage in areas such as Kosciuszko National Park (Natural Heritage Trust 2003) and the bright flowers could visually impact the character of alpine vegetation (Carr et al. 2004).

It can establish on sites with a range of soil and climatic conditions and can tolerate low-nutrient, acidic or disturbed soils (Natural Heritage Trust 2003, Stone 2010). There is therefore a risk of invasion after fire. Espie (2001) noted that some species of hawkweed can alter soil chemistry, organic matter levels and microbial activity under patches.

OHW can invade by vegetative spread (via stolons and rhizomes) and seed production. It is primarily spread by wind, although Williams et al. (2007) noted that seeds are predominantly dispersed within 2 m of a source patch, suggesting long distance wind dispersal is rare. It can also disperse by water, be spread by machinery and invade disturbed areas (roadside, drains, residential areas), ski-fields, grasslands, pastures and alpine meadows and open woodland (Natural Heritage Trust 2003). Minute barbs along the ribs of the seeds means they stick to animal fur, feathers and clothing, providing another mechanism for dispersal (Natural Heritage Trust 2003). One square metre of OHW can produce up to 40,000 seeds a year (Natural Heritage Trust 2003).

In the Central Highlands of Tasmania, OHW will begin flowering early December and by January most flowers are spent. Some rosette clusters will have a flower deeply embedded in it during February and March, but this is rare (K. van Dullemen, Whispering Landscapes pers. comm.). Peak germination in Australia is March to May (Williams et al. 2007 and refs therein). Flowering is influenced by altitude, with later flowering occurring at higher altitude (Williams et al. 2007 and refs therein). It is a facultative apomict (it can produce seeds asexually or without pollination, Bicknell et al. 2003). This asexual reproduction facilitates further dispersal (Williams et al. 2007). The pollen of OHW is allelopathic, limiting the sexual reproduction of other plants by inhibiting pollination, germination of seeds or seedling growth (Espie 2001, Murphy 2001).

Historical records of OHW in Tasmania

OHW is currently limited in its distribution in Tasmania, with known populations at:

- Fern Tree, South Hobart and the Springs at kunanyi/ Mt Wellington
- A number of infestations in grasslands, poor pastures, roadsides, disused Hydro villages and neglected areas across the Central Highlands, including Miena, Poatina Rd near Pump House Bay, Derwent Bridge/ Mt Arrowsmith area, several locations on the Lyell Hwy, Shannon and Butlers Gorge (at disused-Hydro villages), Tarraleah, Maydena, The Steppes, Cattle Hill and Bothwell
- In the past it has also been recorded in Circular Head, Meander Valley (old Quamby Bluff record), Maydena and Kingborough municipalities.

Plants were reported in the nursery trade around 2010, which Biosecurity Tasmania investigated.

The locations of previous and more recent records of OHW are mapped in Section 3 of this report.

If allowed to spread, OHW could be highly detrimental to Tasmania's economy and environment, including the Tasmanian Wilderness World Heritage Area (TWWHA). The preferred habitat of OHW is elevations of 1000 m but it can survive at lower altitudes (e.g. it is present in properties on Davey St, South Hobart which is approximately 300 m above sea level). While it's concentrations at low altitudes is relatively sparse, the risk is it escaping into its optimal, higher altitude (1000 - 1700 m) habitat where it could spread rapidly and cause significant impacts, particularly on natural values.

OHW is difficult to identify when it is not in flower and difficult to control. Known populations have been monitored and controlled for a number of years in Tasmania, with many land managers, landowners and organisations contributing financially and in-kind to control it. However, Tasmania has not maintained a sustained or co-ordinated approach to its control. There is an acknowledged need to identify the most cost-effective means of achieving early detection and control (City of Hobart 2019).

According to the Hawkweeds Statutory Weed Management Plan (Biosecurity Tasmania 2003), it is a Zone A weed across the state and therefore the strategy is "Implement integrated control program for eradication and prevent future occurrences" in the following municipalities:

- Central Highlands
- Circular Head
- Derwent Valley
- City of Hobart
- Kingborough
- Northern Midlands
- Southern Midlands.

In the remaining municipalities, the strategy is prevention and early detection.

In recognition of the need to better understand the distribution of OHW in Tasmania and to identify strategies to eradicate it while it is still in an early invasion stage (in accordance with the generalized invasion curve, Figure 1), Biosecurity Tasmania funded NRM South to:

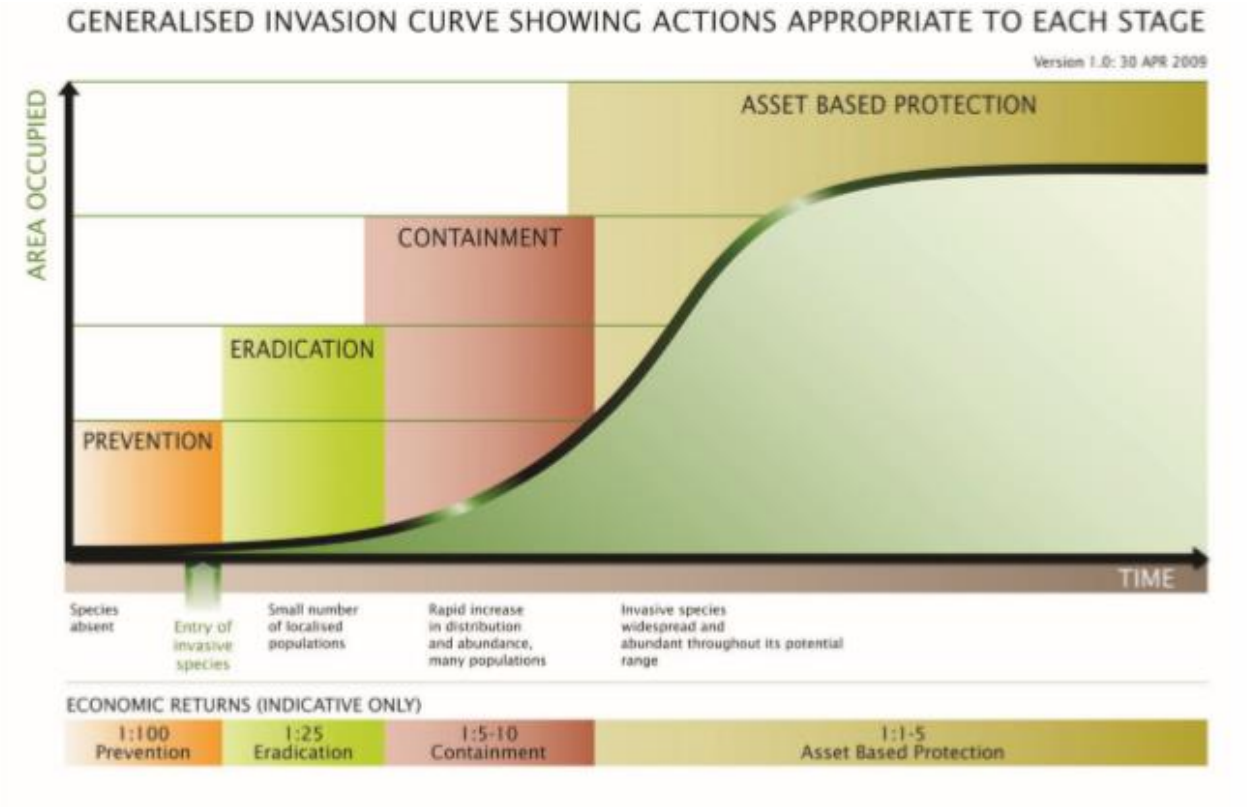
- Identify key stakeholders involved in orange hawkweed (OHW) management
- Re-instigate an OHW Network of key landowners and managers
- Explore alternative funding options such as from the Weed Action Fund to implement actions as agreed by the network
- Delimiting surveillance of potential new sites through a facilitated mapping workshop
- Ground-truthing of mapped delimited surveillance sites
- Increased awareness amongst landholders and land managers in areas at risk of infestations
- Re-assessment of known infestations, particularly for Fern Tree

- Coordinated treatment of agreed sites
- Status report

Once the work commenced, the key deliverables were refined to:

- Identify key stakeholders involved with OHW
- Re-establish the OHW Network
- Map the current known distribution and historical spread of OHW
- Examine the utility of modelling to identify potential new infestations
- Examine the efficacy of using dogs to detect OHW
- Produce a Status Report, including recommendations for future action.

Figure 1. Generalised invasion curve (Source: Victorian Government 2010)



2. Orange hawkweed Network

The OHW Network was re-established in early 2019 and brought together key stakeholders managing the weed. The Network met five times between February and June 2019.

The re-formed OHW Network comprised the following organisations:

- Biosecurity Tasmania
- City of Hobart
- Hydro Tasmania
- Property Services, Tasmania Parks and Wildlife Service

- Central Highlands Council (via the Derwent Catchment Project, DCP)
- Department of State Growth
- Kingborough Council

Specific contractors also attended some OHW Network meetings, including Whispering Landscapes (weed contractor, who has undertaken survey and control work in the Central Highlands area), CSIRO (who developed a model for OHW in the Central Highlands) and Mel Kelly (detector dog work). Sustainable Timber Tasmania (STT) was invited to each meeting but did not attend.

Aside from those involved in the OHW Network, the following land managers were identified as either managing or potentially having OHW on their properties:

- The Cattle Hill Wind Farm (Proponent Wild Cattle Hill Pty Ltd)
- TasWater
- PWS (Tasmanian Parks and Wildlife Service) at Lake St Clair and the Steppes

Information was obtained about the presence and control of OHW from the Cattle Hill Wind Farm and PWS staff at Lake St Clair, but at the time of writing, TasWater had not provided input into the presence and management of OHW on their land. They declined an invitation to join the OHW Network. However, they provided permission to contact their weed contractor, ELS, for information on the presence and treatment of OHW, but although this information was requested on numerous occasions, ELS had not provided it at the time of writing.

All actions that arose during meetings of the OHW Network were completed.

3. Current known extent of occurrence in Tasmania

Data on the currently known distribution of OHW was obtained from the Tasmanian Natural Values Atlas (NVA) and input from key stakeholders. The OHW Network identified that some data from the Central Highlands had not been uploaded to the NVA, so NRM South obtained and uploaded these, then checked all records and removed any repeated data. Figure 2 below presents the currently known distribution of OHW in Tasmania. Note that there are 267 records (marked with orange stars) for which the source and other details are unknown. Investigations were made into these records, but no further details could be found. It is thought the metadata may have been lost during a 'revamp' of the NVA in 2012 (D. Storey NVA, DPIPWE pers. comm.).

Figures 3 and 4 map the distribution of OHW records in the Central Highlands and the Fern Tree/Neika area on the outskirts of Hobart, respectively. Figure 3 demonstrates the close proximity of OHW to both the TWWHA (marked in green) and the areas burnt in the 2018/19 bushfires (marked in yellow). Note that Figure 4 contains records from City of Hobart that had not been uploaded to the NVA at the time of writing (E. Jeffery, City of Hobart pers. comm.).

An attempt was made to map the changes in the distribution of OHW over time using the NVA records. However, this proved impossible as survey effort and areas searched were not consistent over time, therefore changes in observations could not be assumed to reflect movement of the weed. The lack of information on the 267 records exacerbated the problem.

Figure 2. Currently known distribution of orange hawkweed in Tasmania, derived from NVA records.

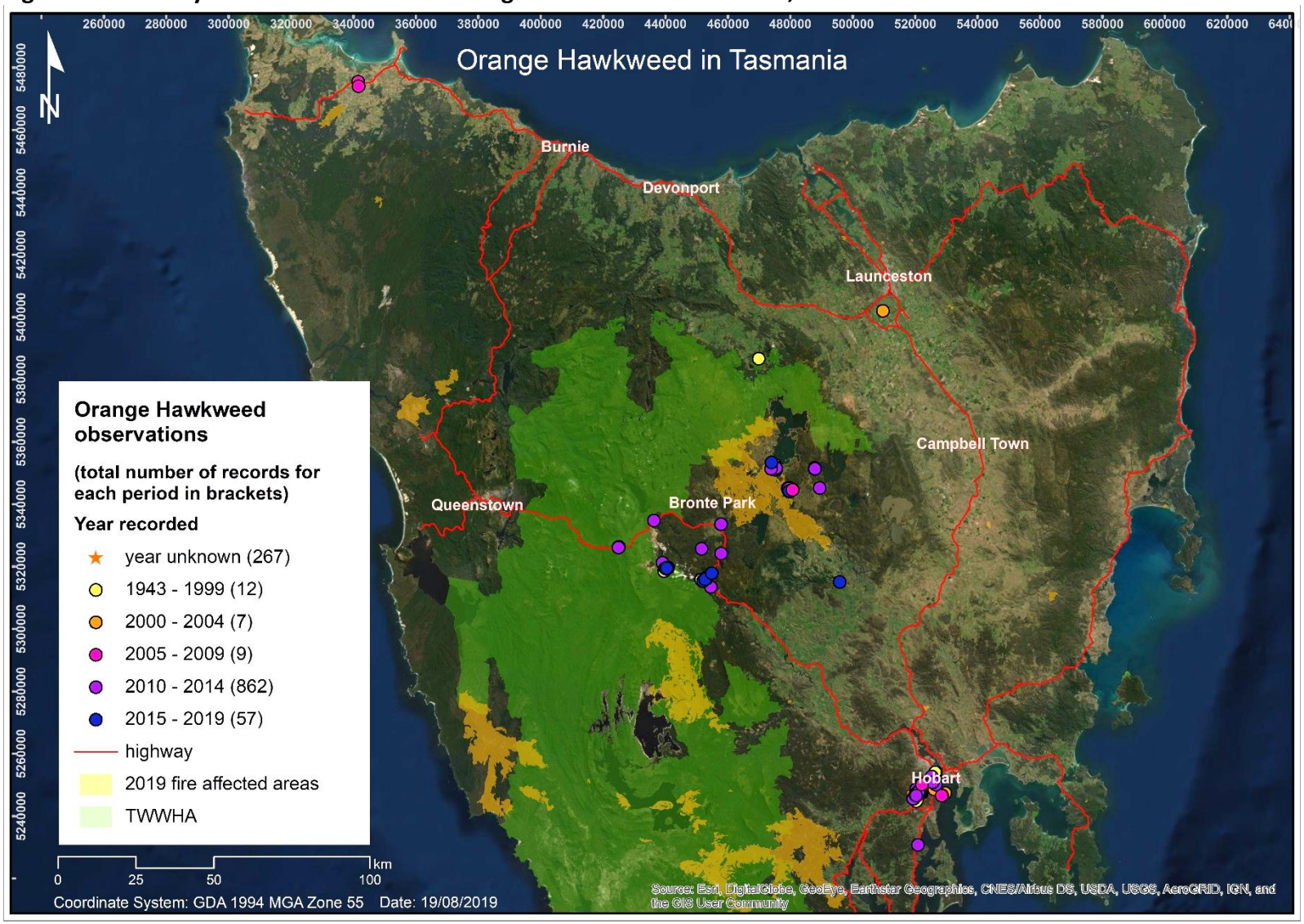


Figure 3. Distribution of orange hawkweed in the Central Highlands of Tasmania, derived from the NVA

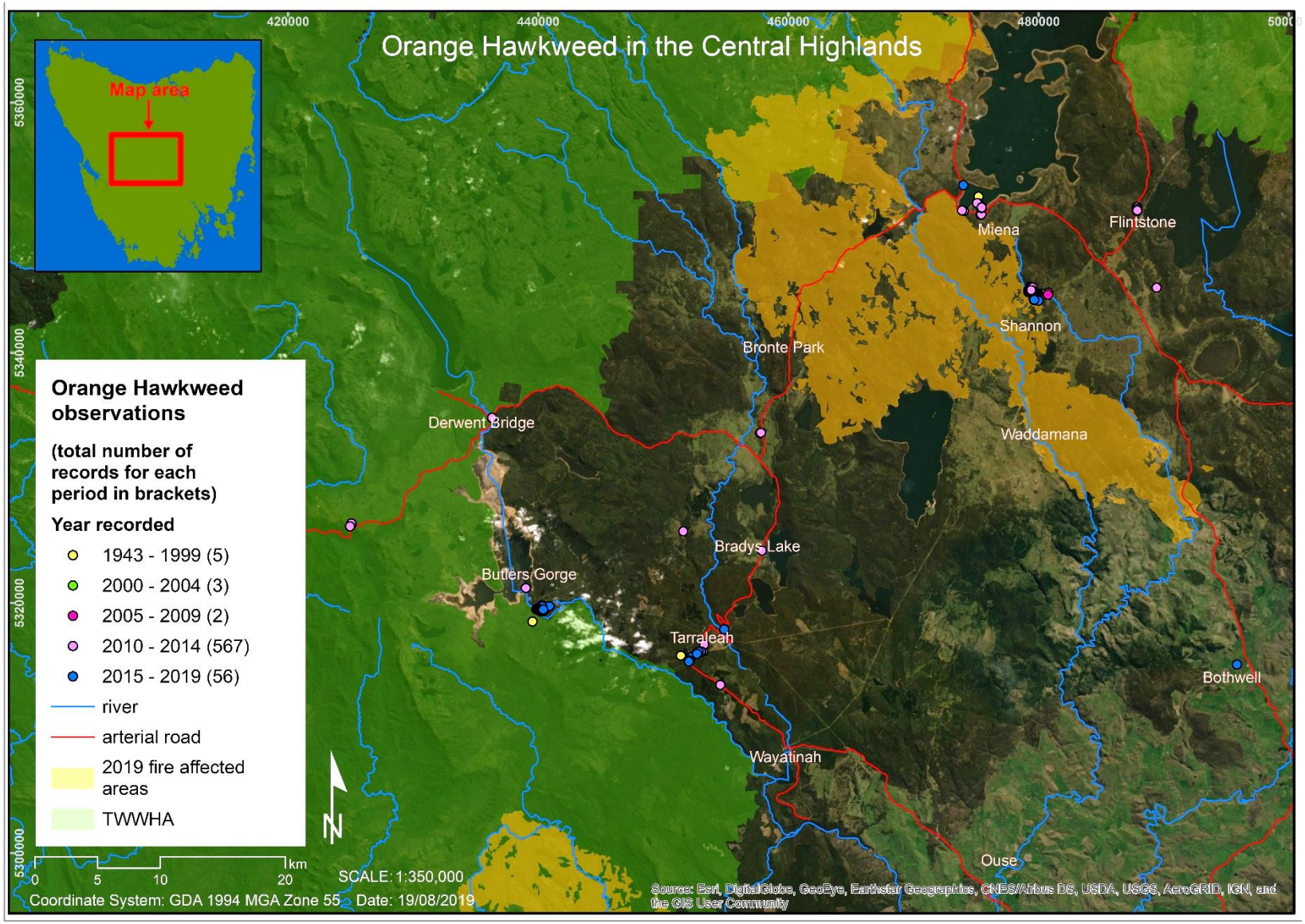
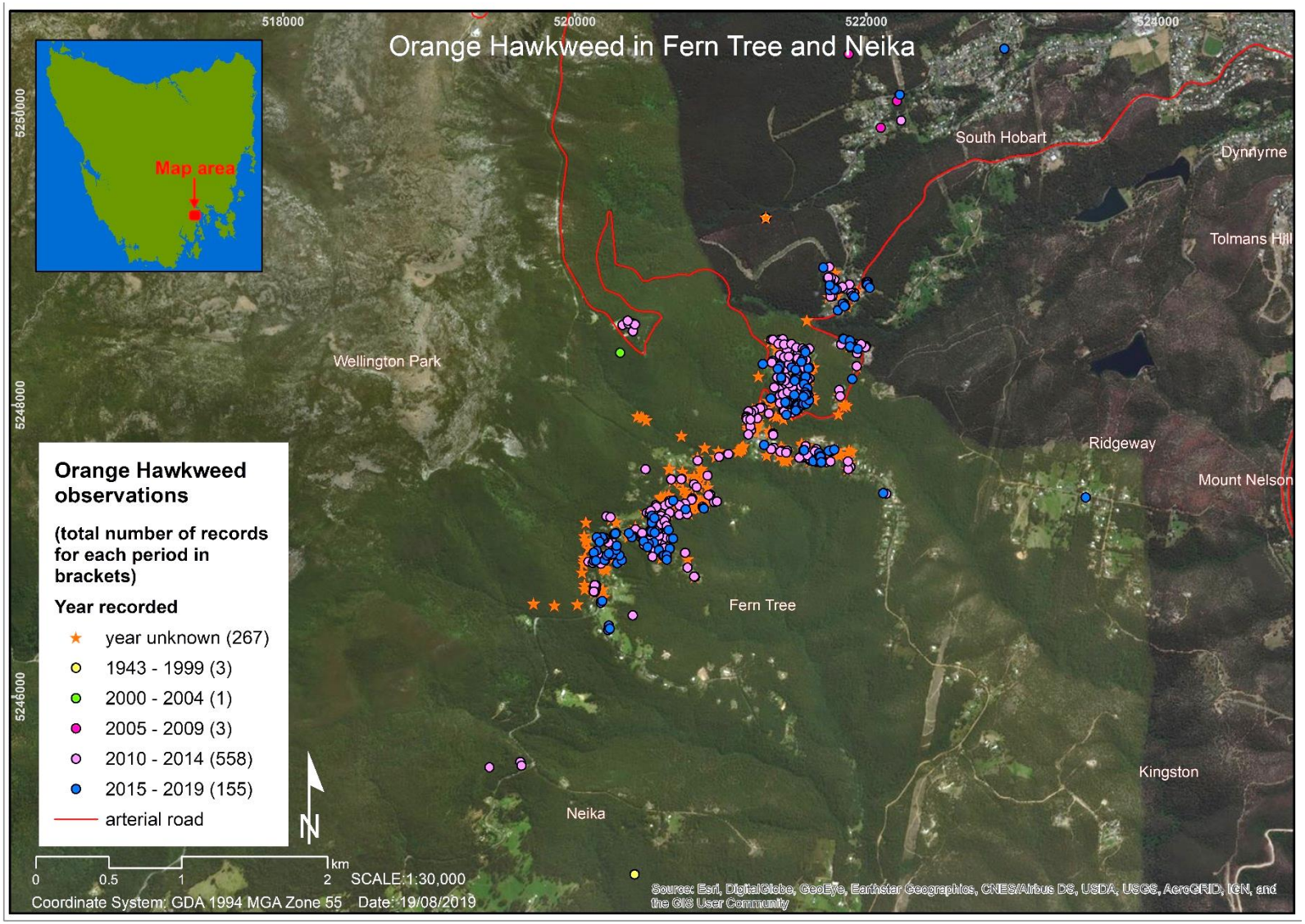


Figure 4. Distribution of orange hawkweed in the Fern Tree/Neika area outside Hobart (Note: data derived from NVA records plus 155 records from City of Hobart that had not been uploaded to the NVA at time of writing)



With the increase in fire events in Tasmania, there is a risk of incursions of OHW into burnt areas, which should be considered during strategic planning for the management of the weed.

Specific input from land managers

City of Hobart

The following are excerpts from the City of Hobart 2019 fact sheet (City of Hobart 2019).

In 2010/2011, 2011/2012 and 2012/13 a Caring for Country grant was received by the Southern Tasmanian Councils Authority (STCA) to survey and treat OHW at properties in Fern Tree and Neika. The City of Hobart worked in partnership with the STCA on awareness raising activities and also controlled all known sites along Council roads and at The Springs on kunanyi/ Mt Wellington. Since this time, City of Hobart has continued to treat infestations on Council land but have not engaged with the private landholders in Fern Tree. Fern Tree is unique in the respect that the weed is found across a multitude of private landowners. For example, in 2018/2019 the City of Hobart sent letters to 446 residents of Fern Tree and South Hobart.

City of Hobart conducted a program on OHW in the summer of 2018/2019 which had the following objectives:

- Revisit private properties last surveyed in 2011/2012
- Establish the extent of orange hawkweed in Fern Tree
- Collect quality data on infestation numbers and distribution and
- Determine the commitments required to execute an eradication program in the City of Hobart.

Two Authorised officers under the *Weed Management Act 1999* were trained to facilitate inspections on private land for this project.

The City developed an ArcGIS App using Collector for data collection in the field and educational materials for landowners. These materials included:

- Orange hawkweed fact sheet
- Orange hawkweed ID sheet
- Orange hawkweed calling card – As authorized officers, properties could be inspected when the landowners were absent, so the calling card informed the landowner that an inspection had occurred.

Community awareness included:

- Landing page on the City of Hobart website
- Feature on Channel 7 Nightly News January 17, 2019
- Article in Hobart Observer February 7, 2019
- Segment with Elise Jeffery on ABC Radio March 02, 2019
- Facilitation of detector dog training also featured on ABC Radio, ABC Facebook, Channel 7 Nightly News, WIN News, the Mercury and Tas Country

A total of 327 properties were surveyed, with the following outcomes:

- 63 had OHW compared to 104 in 2011/2012, however, 18 of the 63 properties with OHW in 2018/2019 were not surveyed 2011/2012
- 1 property OHW 'absent' in 2011/2012 now 'present' in 2012/2019
- 54 properties treated by the City of Hobart (at no expense to landholder)
- 9 properties treated by landowners/contractors

The priorities for the City of Hobart during 2019/20 are:

- Revisit OHW fact sheet, in particular update advice for effective control
- Send letters to properties recorded to have OHW in either 2011/2012 OR 2018/2019
- Survey private properties with large OHW infestations (n = 9)
- Survey remaining private properties found with OHW in 2018/2019 (n = 52)
- Trial landholder incentive scheme with shared cost of treatment between the landowner and the City of Hobart
- Survey all City of Hobart roadsides in the project area
- Treat OHW infestations on City of Hobart land
- Extend bounds of 2018/2019 area – letter drop/inspect properties in South Hobart.

City of Hobart found that OHW has not moved from one property to another in the past five years, with the low rate of flowering limiting its spread. City of Hobart regard public education as essential as most landowners do not know what OHW is and assume it is just another broadleaf in the lawn and are unaware of the damage it can cause (E. Jeffery, City of Hobart pers. comm.).

Kingborough Council

The following comments were received from Kingborough Council.

OHW has not been seen at the previously known location at Channel Highway Lower Snug for well over five years. Given the short seed viability and the fact Weed Officers haven't seen any regrowth from rhizomes, the Council would be surprised if it was ever to be seen there again. Clearly this doesn't exclude any infestations that have not been identified in the Neika area. City of Hobart Council has expressed interest in working co-operatively with Kingborough Council to detect OHW on the boundaries of the two municipalities, specifically in the Neika area (E. Jeffery, City of Hobart pers. comm.).

State Growth

Whispering Landscapes was engaged by State Growth to survey the Squires Creek infestation in 2016-17 and 2017-18, with no plants found. They also treated OHW at and adjacent to Poatina Rd near Flinstone Point Arthurs Lake, as part of a contract with State Growth.

Central Highlands Council (represented by DCP)

OHW is still a major concern in the Central Highlands and while there is evidence of effective control at a number of known sites, the weed has spread to new sites within the municipality. The Derwent Catchment Project (DCP) currently coordinates weed control and management in the Central Highlands municipality and acts as the Weed Officer for the Central Highlands Council. DCP have also been working on OHW at Butlers Gorge and resurveyed sites during 2019 (see DCP 2019).

Tasmanian PWS had funded the Working Neighbour Program to produce a Weed Action Statement for OHW in the Central Highlands (Derwent Catchment Project, DCP, 2019). The focus of this program was OHW records in close proximity to the TWWHA. The program found that OHW was either not present or included a few plants at outlying areas, but still present, although reduced in area at Butlers Gorge and the Shannon. They found some evidence of spread at four sites (Maydena, The Steppes Reserve, Bothwell and Cattle Hill Wind Farm. The latter is discussed in more detail below).

DCP (2019) found that there are 14 known locations of OHW over the 173,771 ha of the Central Highlands, although known infestations are concentrated in 100 ha. Specifically, they found OHW present across the following areas: Shannon (42 ha); Butlers Gorge (22 ha); Miena (19 ha); and Tarraleah (15 ha). There are a further 11 sites with OHW, mostly roadside locations, under 1 ha. DCP regard these figures as an underestimate. DCP (2019) cite the Central Highlands Weed Management Plan which lists 10 known locations of OHW. They state that of the eight additional locations identified by the data review, five are within the Central Highlands Municipality - Bothwell, Bronte Park, Fourteen Mile Rd, Cattle Hill and The Steppes, with all being on private land except Fourteen Mile Rd and The Steppes.

The DCP (2019) data review identified that OHW records not currently entered in the NVA included those for Squires Creek, some data from 2015 Hydro Tasmania surveys, 2019 DCP surveys, State Growth and Central Highlands Council control sites.

The project also included treatment of OHW sites on PWS land at the Steppes and Butlers Gorge, and scheduling of treatment on private land at the Shannon in 2019-20 control season.

DCP (2019) have found control efforts effective at many of the sites in the Central Highlands and provide a suite of recommendations for controlling OHW in the Central Highlands.

Further details are provided in the DCP (2019) report, which will be published shortly.

Whispering landscapes (Central Highlands area)

Whispering Landscapes has been contracted to treat OHW on the Waddamana Road at the Shannon River bridge for nine years, resulting in a reduction in infestations at this site. The control efforts at the Shannon between 2010-2012 were funded by the Australian Government and NRM South via the STCA. Following this, funding for one year was provided through DCP, then a further two years by Crown Land Services, Hydro Tasmania and Central Highlands Council for work on PWS land. Funding for Whispering Landscapes to treat OHW

on Crown Land ended in 2017. Control works are still funded on Hydro Tasmania land and in the road reserve by Central Highlands Council.

When treating OHW at the Shannon River bridge on 30th December 2018, it was noted that extensive road widening works were occurring (associated with Development Application 2018/00031, the Cattle Hill Wind Farm). During this time, a local shack owner indicated that the OHW incursion had expanded to another site along the Waddamana Road at GPS co-ordinates (e) 480458 (n) 5344745 for approximately 700 m towards the Highland Lakes Road GPS co-ordinates (e) 481053 (n) 5345040, and appeared to be associated with road widening works for the wind farm. The southern side of the road had more flowering plants than the northern side (see maps in Appendix 1. Note that the data in these maps are also in Figures 2, 3 and 4 and were produced to assist the modelling work) and the area highlighted in orange. Treated plants and survey areas are detailed in the map key.

The new OHW incursion was larger than anticipated and Whispering Landscapes advised:

- There is a high risk that through machine and soil movement along the Waddamana Road, that OHW plants will be spread to other locations further south towards the Cattle Hill Wind Farm site at Bashan Road
- Unless machinery follows thorough hygiene procedures, OHW could be spread to new areas including further south towards the Cattle Hill Wind Farm site near Bashan Road.

Whispering Landscapes noted that OHW is also present at The Steppes and in the nature strip west of the corner of Homes Road and Gordon River Road/Kallista Road at Maydena, but is being managed by others.

Cattle Hill Wind Farm

A reasonable sized patch of OHW was identified at the Cattle Hill Wind Farm by Van Diemen Consulting (VDC) on behalf of Goldwind Australia (the developer of the wind farm, see Appendix 2). The patch was treated immediately and has not re-occurred. VDC believe that it was transported to the site via animal feed. VDC have searched the remainder of the wind farm site and the larger parcel of land surrounding the wind farm and have not detected it.

Hydro Tasmania

Hydro Tasmania have been managing OHW for nine seasons, with delimited surveys during 2015. They have expressed concern that while they are managing it on their land, surrounding landowners are not managing it, meaning re-introductions are potentially occurring. This is particularly the case in areas adjoining riparian zone at the Shannon. Whispering landscapes has conducted the majority of treatment work on Hydro Tasmania land.

PWS Lake St Clair

The Working Neighbour Project funded by PWS and conducted by DCP was prompted by the need to ensure that OHW did not expand in to the TWWHA and other reserves.

Barry Batchelor (PWS) identified several infestations adjacent to the Lyell Highway adjoining Lake St Clair National Park and had been actively managing some of the sites by working with Wildcare group volunteers. STCA and DPIPWE worked with Barry to locate and map all known sites. These sites were at Derwent Bridge and further west along the Lyell Highway in the Griffiths Creek/ Mt Arrowsmith area. Whispering Landscapes worked with Barry up until his retirement last year on both the Derwent bridge site and the Mt Arrowsmith sites.

Property Services (PWS) had a similar concern to Hydro Tasmania, that surrounding landowners were not managing OHW and it may potentially be reinvading their land.

STT

Sustainable Timber Tasmania indicated their only known infestation was at Butlers Gorge and this had been treated by Whispering Landscapes in the past but is now being managed by DCP.

4. Modelling to predict other potential occurrences

In order to achieve eradication of OHW it is critical to use tools to locate all infestations, particularly those currently unidentified. Given the large areas that may need to be searched for OHW, strategies are required to refine search areas, and modelling is one such tool. While modelling work has been conducted in Victoria (a dispersal constrained habitat suitability model, Williams et al. 2007) and NSW (Natural Heritage Trust 2003), no models have been developed specifically for Tasmania. It is speculated that OHW may be behaving differently in Tasmania than at mainland sites (OHW Network).

Dr Nick Beeton of CSIRO was commissioned, as part of the current program, to develop an OHW model based on data from the Central Highlands. Given the time and budgetary constraints, this model was a trial of concept rather than a full model. The report from the modelling is provided in Appendix 4, but a summary is provided below:

- A simple mechanistic modelling framework was developed and applied to several known incursions in the Central Highlands (using Kathy van Dullemen's data set, see Appendix 1)
- The model used the dispersal mechanisms of wind, water and roads
- Predictions were made on current infestations at the Shannon, Butlers Gorge, Tarraleah and Miena
- The evidence to date indicated that evidence for long-distance dispersal was not showing in the field data, and that wind, road and water-based dispersal was limited
- The model was preliminary and due to the paucity of data, some of the results were likely to be unreliable
- The model has potential, but further work is required, including additional iterations, more field data and trials.

Future modelling should also consider the spread of OHW along powerline easements and incorporate Environmental Domain modelling (D. Graddon, Hydro Tasmania pers. comm.).

As this preliminary modelling work was conducted on data from the Central Highlands it may not function well for the Fern Tree area, given the different conditions and the fact that the Fern Tree infestations are garden based and social/demographic modelling is probably of more value (OHW Network). Further, there is a relationship between age of house and the presence of OHW in Fern Tree, so this could be examined if modelling work was conducted specifically for this area.

Aside from the additional work required on the Tasmanian model, future modelling work should involve liaising closely with the work being conducted in Victoria and NSW.

5. Monitoring and detection strategies

Monitoring

Intensive survey work has been conducted at Kosciuszko National Park in NSW since 2010/11 (Caldwell and Wright 2011). During this time, they developed and trialled a suite of strategies to detect OHW, commencing with:

- Intensive line surveys - using 4 -8 volunteers walking set transects 3 - 5m apart (each person on the end had a GPS to document the route) looking for rosettes. The authors note there was an issue with maintaining concentration
- Rapid line surveys – where volunteers surveyed in zig-zagging lines looking for flowering plants. Obviously, this strategy is restricted to during the flowering season
- Zig-zag surveys – used when weather, light or time was limited
- Timber line surveys – set transects at the interface between grassland and woodland
- Quad bike surveys – looking for flowering plants.

They concluded that the rapid line and timber line survey methods were the most successful at detecting OHW (Caldwell and Wright (2011). Further studies during the 2011/12 season noted that systematic surveys (intensive line surveys) and increased survey effort, through the use of volunteers, improved the detection of infestations.

During the second season, the survey lines were placed closer together and the pace was slowed to increase detection rates (Caldwell and Wright 2012). This is consistent with other studies where hawkweed detection rates were found to increase with survey effort and the number of plants at a location (Moore et al. 2011).

It is estimated that it will take in the order of 20 years for staff and volunteers to detect all OHW infestations in Kosciuszko National Park, hence it has been critical to develop a range of survey strategies, particularly ones suited to remote and difficult sites. Innovative approaches being examined are detector dogs, drones and satellite imagery (Caldwell and Wright 2012). They have also conducted modelling to identify high risk areas, where systematic surveys are being undertaken.

The Progress Reports describing the OHW work in Kosciuszko National Park recommend that the sites, treatments, monitoring and survey methods be well documented (Caldwell and Wright 2011). Monitoring of treatment sites is essential to improve and validate methods of control, as it was found that there was an 81% persistence of OHW at some sites, which was attributed to re-sprouting from stolons and rhizomes. In addition, seeds are thought to persist for up to five years (Caldwell and Wright 2012).

Detector Dogs

Literature review

There is growing recognition worldwide that detection dogs are a highly effective tool for conservation management actions. The use of dogs for conservation emerged in the 1890s when they were trained to detect the New Zealand kiwi and kakapo, both elusive avian species that are difficult to locate and monitor in the wild (Robert and Laporte 1994, Helton

2009). Scent detection dogs are now trained for a wide variety of conservation tasks including detection of pest species (Vice et al. 2009), protected species (Wasser et al. 2012), weeds (Goodwin et al. 2010), bird and bat carcasses beneath wind turbines (Arnett 2006, Paula et al. 2011, Bennett 2012), detection of wildlife scats (Wasser et al. 2004, Long et al. 2007), and pathogens (Alasaad et al. 2012).

In the Australasian region, the use of detection dogs as a tool for conservation is still developing. As the pioneer of conservation dogs, New Zealand has a well-established network of over 80 trained conservation dogs and their handlers. Dog and handler teams are trained and accredited by the Department of Conservation with refresher training courses every year (DOC 2019). In Australia, an accreditation scheme hasn't been established nationally, however, dogs have been successfully trained for a wide range of conservation tasks including detection of Baw Baw Frog (VOA news 2018), Koala scats (Cristescu et al. 2015), spotted-tailed quoll (Leigh and Dominick 2015, Science for Wildlife 2015), antechinus (Threatened Species Recovery Hub 2019), feral cats (Southern Queensland NRM 2017), Alpine stonefly (Australian Geographic 2019), orange hawkweed (Cherry et al. 2016), serrated tussock (Kelly and Gill, 2018), and Bulburin macadamia nut tree (Threatened Species Recovery Hub 2019).

Numerous studies and practical examples in the field demonstrate the efficacy of dogs to detect weeds, pests and diseases with detection rates that far surpass human search capabilities and other survey methods. For example, trained scent detection dogs have 67% greater accuracy compared to humans in detection of small plants of the highly invasive spotted knapweed in western North America (Goodwin et al. 2010). In China, primate scat-detection dogs had a 92% accuracy rate compared to 45% of the human-only team (Orkin et al. 2016). Scat detection dogs in Vermont, USA, were found to have the highest detection rate and probability of detection of black bears, fishers and bobcats compared to survey methods using cameras and hair snares (Long et al. 2007). In Australia, detection dogs have been found to be 19 times more effective in detecting koala scats and 153% more accurate compared to other scat survey methods (Cristescu et al. 2015).

Not all dogs are created equal in their capacity to be successful conservation dogs. The success of an individual dog for scent detection is largely dependent on its temperament and physical capabilities. A review of behavioural and physical characteristics of breeds found that gun dogs (e.g. Labrador Retrievers, English Springer Spaniels) and Herding Dogs (e.g. Border Collie, Australian Cattle Dog, German Shepherds) tend to be more suitable for wildlife detection, however, the individual temperament of the dog has a greater influence on its likelihood of success (Jamieson et al. 2017). Temperament characteristics of an ideal scent detection dog include boldness or nerve strength, strong motivation to play (i.e. searching is perceived by the dog as a game), persistence, ability to cope with stressful situations, willingness to work cooperatively with the handler, social intelligence and independent problem-solving skills (Troisi et al. 2019). Some of these behavioural traits may develop with appropriate training whereas other traits are more influenced by the dog's genetic predisposition (Triosi et al. 2019).

The success of a trained detection dog also depends on cognitive and behavioural factors. Scent detection can be broken down into four key tasks that the dog has to reliably perform:

(i) Search an area, often indicated by its handler
(ii) Locate the target odour
(iii) Follow the target odour to its source and
(iv) Reliably alert at the source of the odour without alerting to non-target odours (Troisi et al. 2019).

Behavioural and cognitive factors can affect any of these four tasks being performed accurately and if one task is not performed well then it impacts on the others. Factors that can include performance of a scent detection dog include the arousal and stress state of the dog, the emotional state and experience of the handler, training methods regimes, prior learning, health status, environmental factors and search methodologies (Troisi et al. 2019).

The stress and arousal states of both the dog and the handler (i.e. as the dog picks up on the stress of its handler) will influence its performance (Troisi et al. 2019). Training methods and regimes, enrichment, socialisation and learning from observing the behaviour of a conspecific dog have all been demonstrated to influence the success of training dogs for scent detection (Johnen et al. 2017, Troisi et. al. 2019). Dogs with prior scent detection training will learn a new scent in the same category of odours more rapidly than a scent from another category (e.g. weeds versus pest species) (Cablk et al. 2008, Johnen et al. 2017).

Training of the handler is just as important as the training of the dog. Handlers need to be trained appropriately to recognize their dog's alert signals as the majority of false negatives are due to the handler moving the dog away without realizing that the dog had detected the target scent (Wasser et al. 2004, Concher et al. 2014). False negatives caused by the handler may also have the effect of reducing the dog's motivation to continue searching for the target scent in the future (Troisi et al. 2019).

In addition, there are several environmental factors that can influence the performance of the dog to detect a scent during a search event. Temperature can greatly influence the olfactory capabilities of dogs. Hot conditions are not only a potential health hazard to the dog but also reduce its olfactory capability as the dog cannot pant and sniff at the same time (Mainland and Sobel 2006, Angle et al. 2014). In extremely driven dogs, the dog may choose to sniff rather than pant which can lead to heat exhaustion (Stanley 1980, Gazit and Terkel 2002). When a dog is sniffing it also produces more saliva to moisten the mouth and nose to concentrate the scent particles. Hence, scent detection dogs have increased water requirements and if these needs are not met dehydration can rapidly occur impacting health and performance of the dog (Baker and Turlejska 1989).

Other environmental factors that can affect scent detection are humidity, wind speed and direction, and topography (Reed et al. 2011). Highly variable wind has been found to increase detection distance and time as it may disperse the scent making it more difficult for the dog to trace the scent back to the source (Shivik 2002). Air moisture can slow down the evaporation rate of the scent source and hence it is easier for dogs to detect scents in more

humid conditions compared to dry conditions (Pearsall and Verbruggen 1982, Reed et al. 2011). Topography may influence detection time; however, several studies have demonstrated that dogs still accurately detect scents in dense, complex habitats and rugged terrain (Long et al. 2007, Dematteo et al. 2008, Leigh and Dominick 2015).

Emma Bennett (Elmoby Ecology) is undertaking a PhD on the use of conservation dogs in Victoria, Australia and has been conducting trials on dogs to assess their efficiency and practical use for weed detection work (including OHW). She has been comparing the ability of dogs and humans, and her results have thus far indicated that dogs excel in exploratory work and finding new patches. She noted that there is an indirect benefit of using dogs in work as they often engage the volunteers and contractors (this would be valuable in areas such as Fern Tree). Dogs do not replace the need for volunteers and contractors/staff in weed programs but augment the searching. (There are also secondary benefits of using volunteers including that participation creates social bonding and a sense that people are contributing to their local environment). Emma confirmed that dogs can detect OHW stolons and rhizomes, and that they cover transect by criss-crossing which is very effective.

Detector dogs need to stop just at or before peak activity or they will lose interest. The duration of work with the dog is not number of hours, but instead patch size and how hard they need to work. Dogs can usually manage morning and afternoon sessions before tiring. Effective detector dog work on weeds needs an ecologist / weed person and a dog handler as each has slightly different roles (E. Bennett, Elmoby Ecology pers. comm.).

In conclusion, dogs are highly effective at scent detection for conservation applications with a very high degree of accuracy. There are, however, many factors that can influence the probability and accuracy of scent detection. The training and experience of the dog-handler team as well as their current emotional and physiological states needs to be considered before conducting a search. The handler also needs to be able to assess environmental conditions to decide on the most appropriate search strategies and methodologies (e.g. sweep widths) to optimise probability and accuracy of detection. Both the dog and handler also need to remain flexible to adjust day to day in order to work in a wide range of weather conditions and variety of habitats and topography (Cablk et al. 2008, Glen et al. 2018, Glen and Veltman 2018).

Detector dog trials

The current project funded the training of “Fonz” to detect OHW. Fonz and his handler had been trained over two years (from eight weeks of age) on the declared weed serrated tussock by experienced conservation dog trainer, Steve Austin (https://www.steveaustindogtrainer.com/). Steve Austin provided an additional four days of training from the 22nd – 25th April 2019 for Fonz and a team of six handlers on OHW. OHW samples had been potted up for use in the training and *in situ* training was undertaken for the first two days. After this, Fonz and the handlers visited field sites at eight private properties in Fern Tree, Hobart, with the City of Hobart to further develop his skills.

Additional training was then conducted in the Central Highlands with Kathy van Dullemen (Whispering Landscapes), at the Shannon on Crown Land, and a brief survey on the edges of

the Waddamana Road near the Shannon River bridge. Fonz and his handlers were subsequently joined by experienced weed detector dog Connor and his handler Ryan (Tate Animal Training Enterprises https://www.tateanimals.com/) from New South Wales. Ryan Tate has worked for many years with Steve Austin and the OHW dogs, Conner and Sally, together with Hillary Cherry from NSW Parks. He was commissioned by the current project to assist with the training of Fonz and the handlers in the Central Highlands.

Half a day was spent on the Tarraleah Golf Course and another half day at Butlers Gorge. The second day was spent continuing training at the Steppes Historic Site and Conservation Area. It was clear that Fonz did not have any difficulty detecting smaller plants but struggled with larger ones (M. Kelly pers. comm.). There were a few sites where the dogs strongly indicated the presence of OHW, although no plants were visible, which might indicate the presence of stolons or rhizomes. Surveys for plants at these sites will be conducted in the future. The tracks that the dogs took during these surveys and plants detected were mapped (Appendix 3). It was Kathy's experience that a well-trained detector dog would be invaluable to detect OHW plants. She advised that known core infestations could still be surveyed and treated by operators, as the dogs nose appears to drop significantly in efficiency and therefore detection when it was saturated by odour. Outlier areas suspected of containing OHW within the landscape are well suited to being surveyed by a dog and handler.

Kathy also recognised that Fonz and his handlers needed as many opportunities as possible to grow their skill base at detection and developing an efficient, methodical and suitable survey method on OHW. She also noted that GIS data needed to be consistently collected from Fonz's collar to ensure cohesive outcomes across a landscape when survey is being completed in conjunction with operator survey and control.

Further involvement from Connor and Ryan to further develop Fonz and his handlers at key sites in the Central Highlands December 2019 and January 2020 would be valuable.

During these additional field trials, any OHW plants found were pinned and marked with way points for later treatment.

Key issues identified during the training were that the:

- Steep slopes and roads in Fern Tree were identified as potential hazards for the dog and handlers, but that this could be managed with careful planning.
- Fern Tree properties are within an urban area so good communication is required to ensure that no other pets are in backyards and that property owners are comfortable having the dog come to search (to date, communication has been facilitated by City of Hobart Bushland Unit staff), and that there was an overall positive response.
- Conditions in the Central Highlands are very different to Fern Tree, hence there are different considerations. One limitation in the Central Highlands may be accommodation options for the handlers and Fonz. In addition, travel times to and from accommodation to survey sites is a consideration.

- The Shannon and Butlers Gorge are littered with the remnants of old homes and outhouses, fences, glass, etc so the safety of the dog needs to be considered.
- Snakes are a significant risk in the warmer months, particularly at the Shannon. Snake aversion training is required for the Fonz.

The OHW Network requested that an estimate of the costs involved in training and maintaining detector dogs be provided. The costs provided in Table 1 below are regarded as the minimum.

Table 1. Minimum costs for training and maintaining detector dogs.

Activity	*Cost*
Initial training on a second scent (i.e. the dog had previously been trained on another weed. This involved Steve Austin for five days and included transport and accommodation). The above costs do not reflect the real cost of training, which is in excess of $20,000 to make a dog proficient on a weed (e.g. training Fonz on serrated tussock required Steve Austin's training, plus handler training and time over at least two years). Once a dog is trained on one weed, it is relatively quick to train the dog on a second scent.	$7205 (note that this does not include handler time)
Kenneling, vet, food	$1182 per annum (this is a bare minimum, and the true cost is likely to be at least twice this)
Biosecurity Tasmania employee to handle dogs	$250-300 per day estimate from Biosecurity Tasmania. However, Ryan Tate and Sue Robinson have indicated that the daily rate will depend on many factors including whether or not it is your dog / whether you trained the dog / your experience and the job in question, including if the job is for a short or long duration, and the location of the work (is travel and accommodation required). Charge out rates will also be influenced by whether the work is for a community group or for-profit company. Mel Kelly estimates a daily rate

Activity	*Cost*
	of between $750 to $1,500, depending on the above variables. It is also key that the necessary insurances (such as Public Liability and Professional Indemnity, etc) are in place and these costs may need to be passed on to the client.

Note that Biosecurity Tasmania requires that dogs older than 12 weeks have a hydatid certificate, when coming from interstate. If a Tasmanian dog goes to the mainland and then returns within two weeks, a certificate is not required. Note that some heartworm medications cover hydatid treatment and other worms, and documentation from a vet or a statutory declaration that they have been treated, is all that is required.

Drones

Drones or Remotely Piloted Aircraft Systems (RPAS) are being used in NSW to detect OHW from the air (Hung and Sukkarieh 2015). The detection process can be automated to detect the bright coloured flowers (Natural Heritage Trust 2003). Drones allow surveys of large areas at low cost and surveys in inaccessible areas. Drone trials have demonstrated the efficacy of autonomous weed detection to detect, map a target a number of species and trials have indicated their utility in remote areas (Hung and Sukkarieh, 2013 and 2015). The optimal height to fly drones to detect OHW was 15 m above the ground to maximise the image resolution of flowers, and the drones needed to move relatively slowly to maximise detection (Hung and Sukkarieh 2015). However, these heights and speeds are likely to vary with different models of drones. Work is being conducted on algorithms to detect OHW outside the flowering season, by identifying the distinctive geometry of the plans and leaves (Hung and Sukkarieh 2015).

6. Treatment strategies

It has been estimated that it will cost in the range of $AU20,000–40,000/ha to eradicate OHW, as it is very labour-intensive to remove (Kompas et al. 2016). This obviously needs to be considered in relation to the impact to natural and agricultural values if not eradicated.

The herbicides being used or trialled in Australia include:

Grazon Extra®	Garlon 600®	Archer®
Tordon®	MCPA®	Lontrel®
Roundup Biactive®	Associate®	

Trials examining the effectiveness of various herbicides have been conducted in Kosciuszko National Park over a number of years and other sites. These are summarised in Table 2 below.

Table 2. Summary of trials conducted examining the effectiveness of herbicides in managing OHW

Details of study	*Treatment*	*Outcome*	*Reference*
2010/11, NSW	Grazon Extra® (at a rate of 500 ml to 100 l water) and Roundup Biactive® (active ingredient glyphosate).	No significant difference both having a good initial kill rate. However, both treatments resulted in plants reappearing later.	Caldwell and Wright 2011
2011/12, NSW	Grazon Extra® and Roundup Biactive®	Biactive® had significantly more kills of non-target species than Grazon Extra®.	Caldwell and Wright 2012
2012/13, NSW	Tordon® granules (advantage of not requiring water). Herbicide application included a 1 m buffer on and around emergent plants and populations.	Results inconclusive Both reduced the number of plants, with Grazon® having a slightly higher result.	
2013/14, NSW	Grazon Extra®, Roundup Biactive®, Tordon® granules and Lontrel. Environmental dye was used in all applications.	All killed plants, with no one herbicide being a standout.	Caldwell and Wright 2014

Details of study	*Treatment*	*Outcome*	*Reference*
2010-15, NSW	Tordon® granules in a range of vegetation and semi-aquatic communities to ensure sustained herbicide activity. The clopyralid-based and broad-leaf selective Lontrel® in semi-aquatic areas, and greater spray buffers being applied to hawkweed plants to ensure herbicide application to all rosettes and stolons.	Achieved a 98.5% reduction in OHW in Kosciuszko National Park.	Hamilton et al. 2015
Alaska	Aminopyralid, a constituent of Grazon Extra® and clopyralid the constituent of Lontrel®.	These were the most effective herbicides for controlling OHW.	Seefeldt and Conn 2011
2010/11, Tas	Garlon 600®, MCPA®, Associate® and Archer®, during March and only assessed for 15 weeks, with growth during the following season not documented.	Results were equivocal.	Meiss 2011, D. Graddon Hydro Tasmania, pers. comm.

The spray method used in Kosciuszko National Park was dependent on the size of the infestation, with larger infestations requiring a spray pack (Caldwell and Wright 2011). Spraying was targeted at the plants, as opposed to boom spraying. Contractors documented the number of treated rosettes, flowering and seeding plants, although some sites did not persist after the initial treatment. They found in this first season that 36% of sites required no further treatment and 42% required one additional treatment. However, it was unknown if this was because of treatment technique or patch density, but they suspected the latter (Caldwell and Wright 2011).

During the initial seasons in NSW they marked untreated sites in blue flagging tape and once treated, changed to pink (Caldwell and Wright 2011). In subsequent seasons they incorporated dye into applications when spraying to monitor how well treatment was applied and decrease the chance of missing plants or doubling up of treatments. Dye was

also used during field inspections to highlight and evaluate 1 m buffers (Caldwell and Wright 2013).

One of the challenges of treating OHW is ensuring the herbicide penetrates the stolons and rhizomes. In an attempt to increase take up of the herbicide in the stolons and rhizomes, treatment at Kosciuszko National Park during 2011/12 was delayed until the plants had increased their ground biomass. During these visits, budding flower and seeding heads were also removed (Caldwell and Wright 2012).

The City of Hobart Fact Sheet recommends selective hand-weeding for small infestations of OHW, Weed and Feed® and selective herbicide (MCPA® and Dicamba®), for the treatment of OHW. However, subsequent experiences of Council staff have found hand-weeding and Weed and Feed® ineffective. City of Hobart reported successful treatment of OHW infestations in 2019 although only a selection of properties was revisited post treatment. City of Hobart used Kamba M® for treatment. However, contractors employed to treat larger infestations at Fern Tree had limited success with treatment during 2019, with an overall success rate of only ~20%. This may have been because the plants had already shutdown when they were treated, hence the herbicide was ineffective. The contractor used Lontrel® for treatment. They note that drought and higher that usual temperatures might also impact the effectiveness of treatment.

Williams et al. (2007) reports that digging and grazing can stimulate the growth of plants from roots/stolons, although studies in the USA suggests that the plants don't survive regular tillage and fertiliser (Brown 1992).

Whispering Landscapes found Associate® very hit and miss. It was highlighted that management of OHW is about technique and timing and that no one herbicide is a silver bullet. The main method to achieve good control results was to sprinkle Tordon® granules around base of plant and saturate into the ground with Grazon® solution and spraying 1 m beyond the last plant seen, with sites receiving three treatments per season.

NRM North, suggested the use of Metsulfuron-methyl, as it is known to be effective on plants with rhizomes and stolons. Concern has been expressed that this herbicide will impact other plants if used in bushland areas (S. Leighton pers. comm.).

Aside from using herbicides, it has been suggested that integrated management techniques in agricultural areas might be effective in controlling OHW, such as using a combination of fertilisers, herbicides, seeding and other techniques to stop its spread and favour other species. For example, it can be controlled by developing pastoral grassland systems using fertiliser and species input, minimising disturbance in intact tall tussock grasslands to limit invasion, strategic grazing to reduce seed spread and the abundance of upright plants (Espie 2001). However, OHW is not widespread in agricultural areas in Tasmania, so this approach is less applicable.

Currently, no one herbicide appears to be significantly more effective than another. Key things to consider in the treatment of OHW are to:

- Use an herbicide treatment that the stolons and rhizomes absorb

- Time treatment correctly. December might be optimal as this is when the rosettes are present
- Detect OHW at low densities to prevent spread, including being able to detect daughter plants in dense veg and rough terrain
- Prevent re-invasion by removing seed heads and flowers
- Consider seed longevity, which can be for up to five years, when planning the duration of treatment

(Caldwell and Wright 2013, Hamilton et al. 2015 and references therein).

Potential adaptability of OHW

Members of the OHW Network suspected that OHW is very adaptable and will likely develop resistance to herbicides. *Heiracium* species are known to be polyploid (often with more than usual two copies of genome) which allows for both sexual and clonal (i.e. not reliant on fertilisation) production of seed plus unusual (and possibly adaptive) combinations of genes.

7. Discussion

Currently there are no documented eradications of weeds in Australia (Hamilton et al. 2015) but clearly there is sound justification, and a National priority, to eradicate OHW throughout Australia due to the risk to natural and agricultural values. The Hawkweeds Statutory Management Plan is consistent with this objective. The challenge with eradication is to find the last plant, which will necessitate surveying large areas, and is likely to require tools such as drones and detector dogs (Hamilton et al. 2015). Panetta et al. (2011) suggested that the average time to eradicate a Class 1 weed from Queensland was 18.2 years, and the average total cost of eradication was estimated at $2.997 million. Therefore, if eradication is to be achieved, the investment will need to be substantial and action conducted over a number of years (in the order of five plus years to address seed viability) and well-coordinated. Weed eradication programs require sound planning and protocols to establish containment while working towards eradication (Caldwell and Wright 2017). This means decreasing the risk of weed spread by eliminating seed and plant dispersal and exhausting the seed soil reserve, a strategy that is currently being achieved in NSW and Victoria. The use of mechanisms available under the new Biodiversity Bill should be considered to ensure coordination and compliance to eradicate OHW.

The infestations of OHW in Tasmania appear to be predominantly in two regions, Fern Tree and the Central Highlands. However, there are records further afield, including the northwest coast and it is possible that there are unknown infestations in other areas. Further delimiting surveys to determine the full extent of OHW are required. Environmental domain modelling and improved detailed distribution modelling could be valuable tools to assist with identifying priority areas for searching for infestations, but the modelling initiated as part of this study requires more development and trials. The incidence of fires in the TWWHA and other reserves should also be considered when identifying areas to be searched, as OHW will potentially invade burnt areas.

Once priority areas to be searched are refined (that is, beyond what is already broadly known) the methods for delimiting surveys needs to be determined. This should be informed by the approaches trialled in places like Kosciuszko National Park and adjusted to suit the specific sites in Tasmania. This evaluation should include determining when tools such as drones, dogs, volunteers and satellite imagery could be utilised. It is critical that surveys are carefully planned and all data documented, including treatments undertaken. Survey data should be held in databases available to relevant stakeholders.

Reviews of the literature and discussions with contractors suggest there are different views as to which treatment options are most effective for OHW, with some trials finding equivocal differences. There is general agreement that the herbicide used must be taken up by the stolons and rhizomes so the timing of treatment is important. Some herbicides impact other species of plants so this needs to be considered in areas with bushland or important natural values, such as the TWWHA and other reserves. It may be necessary to conduct more comprehensive trials on the effectiveness of different herbicides in co-operation with NSW and Victoria to obtain clarity as to the best control method.

It is also essential that flowers and seed heads are removed to prevent the setting of seed, as the eradication target relies on no infestation setting seed and then the exhaustion of the seedbank over approximately five years. While some authors propose that a more holistic approach be taken in the treatment of OHW, with other species being planted in treated areas to provide competition to OHW, OHW is not currently widespread in agricultural areas in Tasmania, hence this approach is less relevant. Hygiene practices are a critical component to prevent its spread. Whatever the treatment strategy used, a multi-year program will be required to monitor treated areas and re-treat as required.

A partnership approach similar to that described by Herbert et al. (2013) and used in places like NSW is likely to enhance the success rate. The purpose of such partnerships is to share resources, streamline work and reduce any repetition, collaborate in the engagement and education of stakeholders, and share scientific and other findings with members. The OHW Network is an obvious group to undertake these tasks.

One of the challenges the OHW Network faced over the last six months was the lack of engagement from a small number of key agencies/groups and the lack of engagement with private landowners. Although these agencies/groups were approached on numerous occasions some still had not provided information, or provided only minimal input, at the time of writing. This issue needs to be addressed/resolved in future.

8. Recommendations

The following are recommended:

1. Partnerships and Collaboration

- Continue the OHW Network with the key land managers, such as Biosecurity Tasmania, State Growth, City of Hobart, Kingborough Council, Central Highlands Council and other relevant Councils. Expand the Network as required
- Collaborate with other NRM regions (e.g. NRM North as there are records at Quamby Bluff, and NRM Cradle Coast for the downstream areas of Griffith Creek and surveys of other Hydro village area in the northwest region) and other practitioners working on weed control
- Liaise regularly with the National Hawkweed Working Group and other groups working on OHW elsewhere in Australia.

2. Legislation, Planning and Funding

- Understand mechanisms available under the Biodiversity Bill and prepare management plans, area declarations and orders ready for when the Bill is gazetted
- Ensure that Biodiversity Tasmania coordinates or delegates the coordination of the management plan
- Ensure that ongoing funding from Biosecurity Tasmania is available for at least coordination, modelling, survey, determination of most effective treatment and monitoring of results of treatment.

3. Surveys and Monitoring

- Refine and list the areas for delimiting surveys to contain the spread, informed by further modelling work
- Complete environmental domain modelling
- Expand surveys on private land surrounding Miena, Shannon, Waddamana Road areas and South Hobart (and other areas as identified).
- Develop rigorous survey strategies for finding new infestations and monitoring informed by work conducted elsewhere, particularly that being done at Kosciuszko National Park in NSW (see Caldwell and Wright 2011, 2012 and 2013, Caldwell et al. 2017 or liaise directly ph: 1300 361 967)
- As part of the above, evaluate when other tools such as dogs, drones and satellite imagery would be the most effective method of detection
- Evaluate the value in establishing a volunteer program, perhaps as part of Wildcare, to survey priority areas and treat infestations (similar to what is being done by Parks Victoria and in NSW, e.g. Caldwell and Wright 2011, Parks Victoria 2019).

4. Control and Treatment strategies

- Treat to ensure that herbicides penetrate the stolons and rhizomes

- Prevent spread by removing seed heads and flowers to prevent seed set and dispersal
- Collaborate with NSW and Victoria and/or consider further herbicide trials to determine the most effective treatment strategies in each environment e.g. lowlands (South Hobart / Fern Tree, compared with highland areas)
- Ensure that all contractors and surveyors use best practice hygiene practices
- Consider an ecosystem wide strategy (including what other invasive species might fill the void) when eradicating OHW
- Encourage all contractors and land manager to upload OHW data to the NVA
- Develop a weed register/database to document treatment of infestations, which relevant parties can access.

5. Community awareness

- Raise the profile of OHW and its threat to natural and agricultural values, potentially via a communication plan
- Note that dogs are a useful technique for engaging people
- Educate the community about identification
- Educate the community about hygiene and preventing the spread of seed. Disseminate information on washdown guidelines (e.g. https://dpipwe.tas.gov.au/Documents/Weed%20%20Management%20and%20Hygiene%20Guidelines.pdf)
- Raise awareness in the Central Highlands, Kingborough, Hobart and Derwent Valley municipalities to encourage reporting of potential plants in the Bothwell, Wayatinah, Tarraleah, Derwent Bridge, Bradys Lake, Bronte Park, Miena, Lake St Clair, Westerway/ Maydena, Huonville/ Geeveston, Poatina, Golden Valley and Meander Valley areas.
- Contact Freshwater Angling (trout) clubs Include in Trout fishing magazines, events and lodges, stores, petrol stations, construction projects, etc across the Central Highlands and adjoining areas
- Publish articles in TFGA newsletter, etc
- Raise Awareness in the South Hobart/Ridgeway/ Neika areas. In these areas, the most effective strategy is to educate landholders through targeted letter drop and local Bushcare groups
- Work with the Friends of the Steppes
- Work with specific private landowners to determine if OHW is present at their properties in the Central Highlands.

9. References

Alasaad S, Permunian R, Gakuya F, Mutinda M, Soriguer R and Rossi L. 2012. Sarcoptic-mange detector dogs used to identify infected animals during outbreaks in wildlife. BMC Veterinary Research 8:110-118.

Angle CT, Wakshlag JJ, Gillette RL, Steury Y, Haney P, Barrett J & Fisher T. 2014. The effects of exercise and diet on olfactory capability in detection dogs. Journal of Nutritional Science 3 (e44): 1-5.

Arnett EA. 2006. Preliminary evaluation on the use of dogs to recover bat facilities at wind energy facilities. Wildlife Society Bulletin 34: 1140-1145.

Australian Geographic 3 May 2019. Detection dogs successfully trained to sniff out endangered insects. Available from: https://www.australiangeographic.com.au/news/2019/05/detection-dogs-successfully-trained-to-sniff-out-endangered-insects/?fbclid=IwAR3erqu4P9n0dF7zpD080UokCeH_wJVCax7u0rUUtHu-Jba_TC6Ne-IRxVk [Date last accessed: 5 July 2019].

Baker MA and Turlejska E. 1989. Thermal painting in dehydrated dogs: effects of plasma volume expansion and drinking. European Journal of Physiology 413: 511-513.

Bennett E. 2015. Observations from the Use of Dogs to Undertake Carcass Searches at Wind Facilities in Australia. In: Hull C, Bennett E, Stark E, Smales I, Lau J, Venosta M. (eds) Wind and Wildlife. Springer, Dordrecht

Bicknell R, Lambie S and Butler R. 2003. Quantification of progeny classes in two facultatively apomictic accessions of *Hieracium*. Hereditas 138: 11-20.

Biosecurity Tasmania 2003 (updated 2011). Hawkweeds – Statutory Management Plan. https://dpipwe.tas.gov.au/Documents/Hawkweed_WMP_2011.pdf

Brinkley T and Bomford M. 2002. Agricultural sleeper weeds in Australia: what is the potential threat? Bureau of Rural Sciences, Canberra, Australia.

Brown D. 1992. Estimating the composition of a forest seed bank: a comparison of the seed extraction and seedling emergence methods. Canadian Journal of Botany. 70(8): 1603-1612. Cardwell and Wright 2013.

Caldwell J and Wright G. 2011. Orange Hawkweed Control Program, Annual Report 2010/11. Unpublished Report OEH 2011/0566. Office of Environment and Heritage, New South Wales National Parks and Wildlife Service

Caldwell J and Wright G. 2012. Orange Hawkweed Control Program, Annual Report 2011/12. Report OEH 2012/0807. Office of Environment and Heritage, New South Wales National Parks and Wildlife Service.

Caldwell J and Wright G. 2013. Orange Hawkweed Control Program Report 2012/13. Office of Environment and Heritage, New South Wales National Parks and Wildlife Service.

Caldwell J and Wright G. 2014. Orange Hawkweed Control Program Report 2013-14. Office of Environment and Heritage, New South Wales National Parks and Wildlife Service.

Caldwell J, Turner P and Wright G. 2017. Orange hawkweed eradication program 2014-2016 Report. NSW and Office of Environment and Heritage.

Cablk ME, Sagebiel JC, Heaton JS and Valentin C. 2008. Olfaction-based detection distance: a quantitative analysis of how far away dogs recognize tortoise odor and follow it to source. Sensors 8: 2208-2222

Carr G, Roberts N, Wearne L and Miller T. 2004. Alpine National Park post-fire mapping of orange hawkweed and other pest plants. Ecology Australia Pty Ltd for Parks Victoria.

Cherry H, Constantine A, Primrose K, Hauser C and Tasker K. 2016. It takes a village: detection dogs, partnerships and volunteers aid in hawkweed eradication in mainland Australia. Twentieth *Australasian Weeds Conference*. Available from: https://theaustralianalps.files.wordpress.com/2018/01/0129-hawkweed_cherry_etal_2016.pdf [Date last accessed: 8 July 2019]

City of Hobart 2019. Fact Sheet: Orange hawkweed. https://www.hobartcity.com.au/City-services/Vegetation-management-programs/Orange-hawkweed-control-program

Concher A, Mills DS, Feugier A, Zulch H, Guest C, Harris R and Pike TW. 2014. Using sniffing behaviour to differentiate true negative from false negative responses in trained scent-detection dogs. Chem. Senses 39: 749-754.

Cristescu RH, Foley E, Markula A, Jackson G, Jones D and Frère C. 2015. Accuracy and efficiency of detection dogs: a powerful new tool for koala conservation and management. Scientific Reports 5: 8439.

DCP (The Derwent Catchment Project) 2019. DRAFT Orange hawkweed in the Central Highlands. Weed Action Statement 2019-2024. June 2019.

Dematteo KE, Rinas MA, Sede MM, Davenport B, Argüelles CF, Lovett K and Parker PG. 2008. Detection dogs: an effective technique for bush dog surveys. The Journal of Wildlife Management 73(8): 1436-1440.

Department of the Environment and Energy 2019. National weeds lists. Available from: http://environment.gov.au/biodiversity/invasive/weeds/weeds/lists/ [Date last accessed: 16 July 2019]

DOC. 2019. *Conservation Dogs Programme.* Department of Conservation, New Zealand government. Available from: https://www.doc.govt.nz/our-work/conservation-dog-programme/ [Date last accessed: 8 July 2019]

Espie P. 2001. *Hieracium* in New Zealand: ecology and management. AgResearch, Mosgiel.

Gazit I and Terkel J. 2002. Explosives detection by sniffer dogs following strenuous physical activity. Applied Animal Behaviour Science 81: 149-161.

Glen AS and Veltman CJ. 2018 Search strategies for conservation detection dogs. Wildlife Biology 2018: wlb.00393

Glen AS, Russell JC, Veltman CJ and Fewster RM. 2018. I smell a rat! Estimating effective sweep width for searches using wildlife-detector dogs. Wildlife Research 45: 500-504.

Goodwin KM, Engel RE and Weaver DK. 2010. Trained dogs outperform human surveyors in the detection of rare spotted knapweed (*Centaurea stoebe*). Invasive Plant Science and Management 3: 113-121.

Hamilton MA, Cherry H and Turner PJ. 2015. Hawkweed eradication from NSW: Could this be 'the first'? Plant Protection Quarterly 30(3): 110-115.

Helton WS. 2009. Introduction to the science of working dogs. In: Helton WA (ed.) Canine Ergonomics: The Science of Working Dogs. Boca Raton FL: CRC Press. pp. 1-15.

Herbert K, Curran I, Hauser C, Hester S, Kirkwood A, Derrick B and King D. 2013. All eyes focussed on hawkweed eradication in the Victorian Alps – A partnerships approach. P. 140-145.

Hung C. and Sukkarieh S. 2013. Robotic aircraft and intelligent surveillance system for weed detection. P. 90-94 Proceedings of the 17th NM Weeds Conference.

Hung C. and Sukkarieh S. 2015. Using robotic aircraft and intelligent surveillance systems for orange hawkweed detection. Plant Protection Quarterly 30(3): 100-102.

Jamieson LT, Baxter GS and Murray PJ 2017. Identifying suitable detection dogs. Applied Animal Behaviour Science 195 (2017): 1-7. https://www.researchgate.net/publication/317845514_Identifying_suitable_detection_dogs

Johnen D, Heuweiser W and Fischer-Tenhagen C. 2017. An approach to identify bias in scent detection dog testing. Applied Animal Behavioural Science 189: 1-12.

Kelly M and Gill N. 2018. Using detection dogs as part of an integrated weed management strategy – a local government perspective. *21st Australasian Weeds Conference*. Pp. 373. Available from: http://caws.org.nz/old-site/awc/2018/awc201813731.pdf [Date last accessed: 8 July 2019].

Kompas T, Chub L, Nguyen HTM. 2016. A practical optimal surveillance policy for invasive weeds: An application to Hawkweed in Australia. Ecological Economics 130: 156-165.

Leigh KA and Dominick M. 2015. An assessment of the effects of habitat structure on the scat finding performance of a wildlife detection dog. Methods in Ecology and Evolution 6: 747-752.

Long RA, Donovan TM, Mackay P, Zielinski WJ, Buzas JS. 2007. Comparing scat detection dogs, cameras, and hair snares for surveying carnivores. Journal of Wildlife Management 71(6): 2018-25.

Mainland J & Sobel N. 2006. The sniff is part of the olfactory percept. Chemical Senses 31: 181-196.

Meiss A. 2011. Orange hawkweed herbicide trail, Fern Tree Tasmania. STCA

Moore JL, Hauser CE, Bear JL, Williams NSG, McCarthy MA. 2011. Estimating detection-effort curves for plants using search experiments. Ecological Applications 21(2): 601-607.

Murphy SD. 2001. The role of allelopathy in weed ecology. Weed Technology 15(4): 867-872.

Natural Heritage Trust. 2003. Weed Management Guide: Orange Hawkweed (*Hieracium aurantiacum*). Alert list for environmental weeds. CRC Weed Management.

Orkin JD, Yang Y, Yang C, Yu DW and Jiang X. 2016. Cost-effective scat-detection dogs: unleashing a powerful tool for international mammalian conservation biology. Scientific Reports 6: 34758.

Panetta FD. 2014. Weed eradication feasibility: lessons of the 21st century. Weed Research 55, 226-38.

Paula J, Leal MC, Silva MJ, Mascarenhas R, Costa H and Mascarenhas M. 2011. Dogs as a tool to improve bird-strike mortality estimates at wind farms. Journal for Nature Conservation 19: 202-208.

Parks Victoria 2019. 2018/2019 Falls Creek Hawkweed Season Volunteer Newsletter June 2019. file:///C:/Users/chull/AppData/Local/Microsoft/Windows/INetCache/Content.Outlook/RPFKLXDL/Hawkweed%20Volunteer%20Newsletter_2018_2019.pdf

Pearsall MD and Verbruggen 1982. Scent: training to track, search, and rescue. Alpine Publications, Loveland, Colorado, USA.

Reed SE, Bidlack AL, Hurt A and Getz WM. 2011. Detection distance and environmental factors in conservation detection dog surveys. Journal of Wildlife Management 75(1): 243-251.

Robert M and Laporte P. 1994. Field techniques for studying breeding Yellow Rails. Journal of Field Ornithology 68(1): 6-63.

Science for Wildlife. 2015. Detection Dogs. Available from: https://scienceforwildlife.org/detection-dogs/ [Date last accessed: 5 July 2019]

Seefeldt S and Conn JS. 2011. Control of Orange Hawkweed (*Hieracium aurantiacum*) in Southern Alaska; Invasive Plant Science and Management, 4, January – March 2011.

Sheehan, M., James, R. and Blood, K. 2018. Looking for weeds: search and detect guide (2nd Edition). A guide for searching and detecting weeds at the early stage of invasion on public land in Victoria. Department of Environment, Land, Water and Planning, Victoria.

Shivik JA 2002. Odor-adsorptive clothing, environmental factors, and search-dog ability. Wildlife Society Bulletin 30: 721-727.

Southern Queensland NRM. 23 March 2017. Sniffer dogs track feral cats in Western Queensland. Available from: https://youtu.be/qVguNGinyIk [Date last accessed: 5 July 2019]

Stanley SM 1980. A study of heat stroke and heat exhaustion in the dog. Iowa State University Veterinarian 42: 24-27.

Stone KR 2010. *Hieracium aurantiacum*. In Fire Effects Information System (FEIS). US Department of Agriculture., Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: https://www.fs.fed.us/database/feis/plants/forb/hieaur/all.html

Terrett P. 2013. Hawkweed surveillance in the Alps. P. 101 Proceedings of the 17th NSW Weeds Conference.

Threatened Species Hub 2019. Project 4.4.11. Using detection dog techniques to conserve Queensland's endangered montane species. Project Leaders: Diana Fisher, Andrew Baker. Available from: http://www.nespthreatenedspecies.edu.au/projects/using-detection-dog-techniques-to-conserve-queensland-s-endangered-montane-species?fbclid=IwAR1FIypax5HEeQ800FqibWT8QUtgouZkRfB6JTJKB2JLyhND0PDfAIWSGpo [Date last accessed: 5 July 2019]

Troisi CA, Mills DS, Wilkinson A and Zulch HE. 2019. Behavioural and cognitive factors that affect the success of scent detection dogs. Comparative Cognition and Behavior Reviews 14: 51-76.

Vice DS, Engeman RM, Hall MA and Clark CS 2009. Working dogs: the last line of defence for preventing dispersal of tree snakes from Guam. USDA National Wildlife Research Center – Staff Publications. 902: 195-204.

Victorian Government (2010) Invasive plants and animals policy framework. Department of Primary Industries, Melbourne. ISBN 978-1-74217-878-3 (print); ISBN 978-1-74217-884-4 (online). VOA news. 1 August 2018. Conservation detection dogs sniff out threatened species. Available from: https://youtu.be/1iBkqib_k2k [Date last accessed: 5 July 2019]

Wasser SK, Davenport B, Ramage ER, Hunt KE, Parker M. Clarke C et al. 2004. Scat detection dogs in wildlife research and management: application to grizzly and black bears in the Yellowhead Ecosystem, Alberta, Canada. Canadian Journal of Zoology 82(3): 475-92.

Wasser SK, Hayward LS, Hartman J, Booth RK, Broms K, Berg J, Seely E, Lewis L & Smith H. 2012. Using detection dogs to conduct simultaneous surveys of Northern Spotted (*Strix occidentalis caurina*) and Barred Owls (Strix varia).

Williams NSG, Hahs AK, Morgan JW and Holland KD. 2007. A dispersal constrained habitat suitability model for Orange Hawkweed (*Hieracium aurantiacum*) on the Bogon High Plains, Victoria. Parks Victoria Technical Report No. 38. Parks Victoria, Melbourne.

Williams, N.S.G. and Holland, K.D. 2007. The ecology and invasion history of Hawkweeds (*Heiracium* species) in Australia. Plant Protection Quarterly, Vol.22 (2).

Additional reading and resources

Agriculture Victoria (Department of Economic Development, Jobs, Transport and Resources). 2016. Hawkweed eradication protocol: Highland sites.

Agriculture Victoria (Department of Economic Development, Jobs, Transport and Resources). 2016. Treatment, monitoring and eradication methodology Hawkweed (*Pilosella* spp.) – Lowland sites.

https://www.fs.fed.us/database/feis/plants/forb/hieaur/all.html

Biosecurity Tasmania https://dpipwe.tas.gov.au/invasive-species/weeds/weeds-index/declared-weeds-index/hawkweed

City of Hobart https://www.hobartcity.com.au/City-services/Vegetation-management-programs/Orange-hawkweed-control-program

City of Hobart feature https://spaces.hightail.com/space/o6retC2N0p

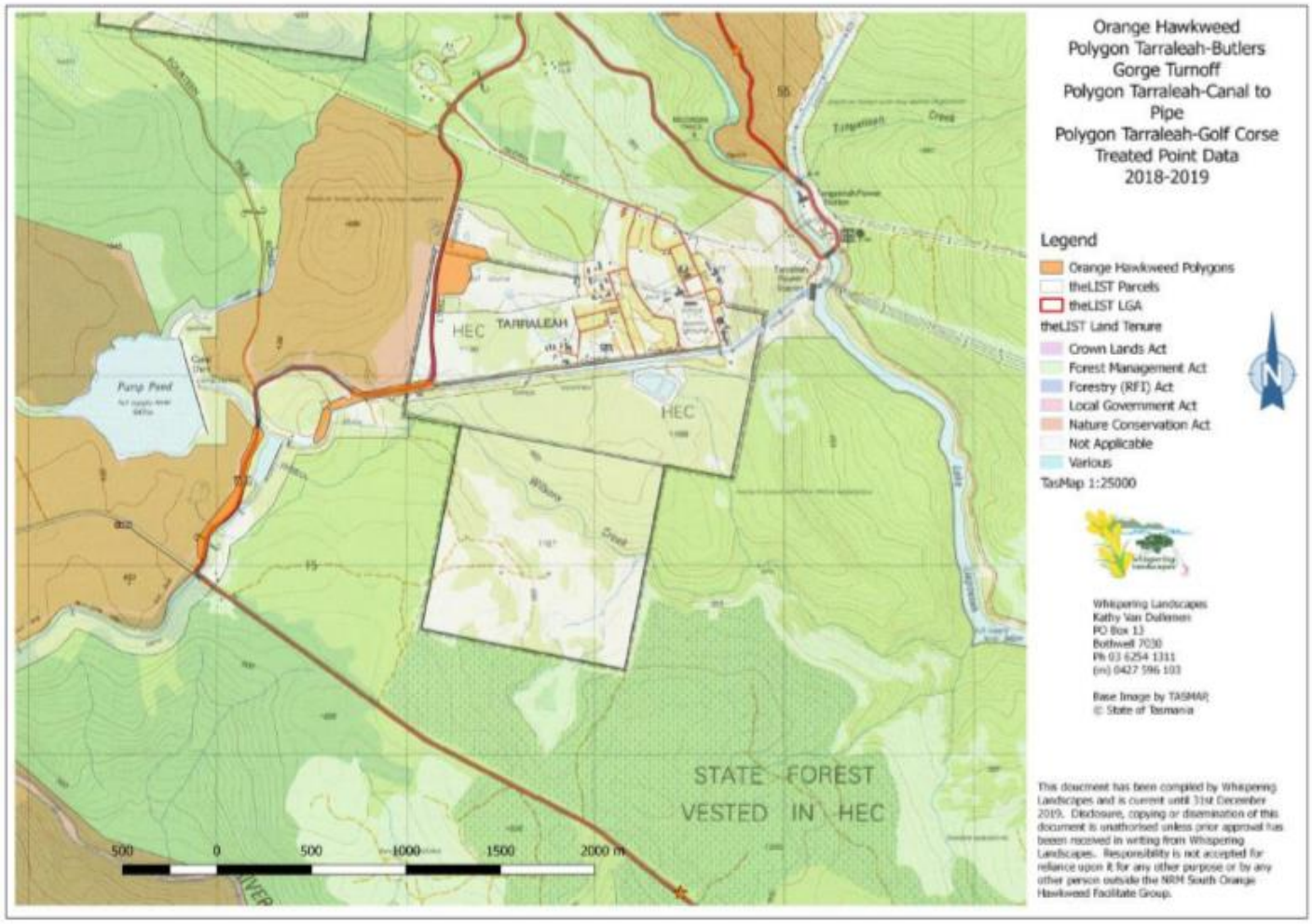
https://www.abc.net.au/radio/hobart/programs/statewideweekends/orange-hawkweed/10867440

Constantine A, Hauser CE, Primrose K and Smith N. 2016. Hawkweed (*Hieracium* spp.) surveillance: development of a targeted and robust plan for the Victorian Alps. Plant Protection Quarterly 31(1): 28-32.

Hauser CE and McCarthy MA. 2009. Streamlining 'search and destroy': cost-effective surveillance for invasive species management. Ecology Letters 12: 683-692.

Appendix 1 Location of OHW treatment in the Central Highlands by Whispering landscapes

Map 1 (note these data are also provided in Figures 2, 3 and 4)



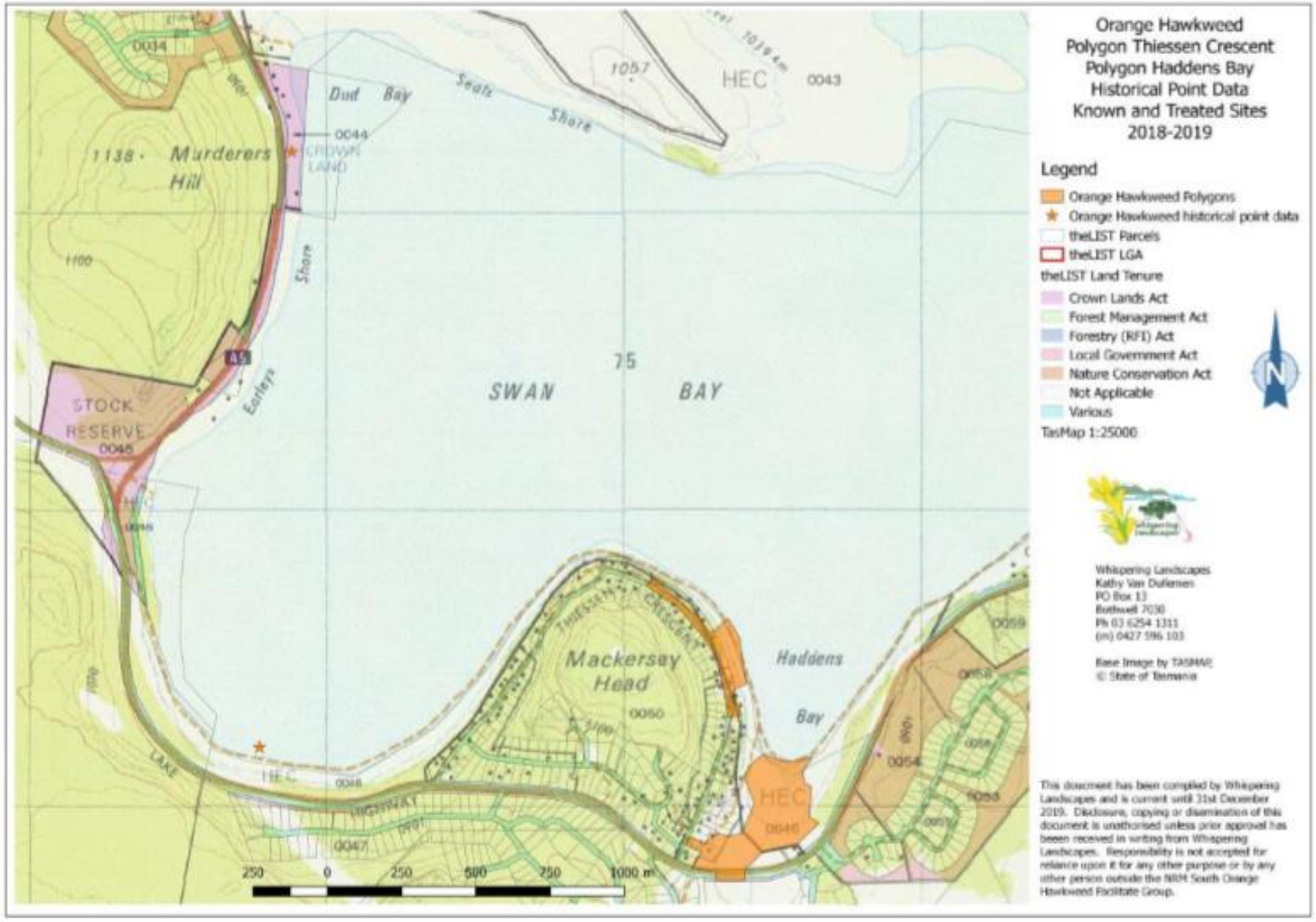
Polygon;

- Lyell Highway Tarraleah-Butlers Gorge turnoff to road bridge over Number 2 Canal. Multi-land tenure site. Since primary treatment 3 years ago overall a significant reduction in Orange Hawkweed plants due to effective and timely herbicide treatment.
- Lyell Highway - Tarraleah - where canals 1 & 2 meet and run into large pipes. Multi-land tenure site. Since primary treatment 3 years ago overall a significant reduction in Orange Hawkweed plants due to effective and timely herbicide treatment.
- Lyell Highway - Tarraleah Golf Course. Multi-land tenure site, overall a slight reduction in Orange Hawkweed plants. Golf Course is a vast flat mown area which parts of are prone to dryness. Site would benefit from sniffer dog trials.

Point Data;

- Lyell Highway Tungatinah Hill, couple of plants present have not been eradicated from site.
- Lyell Highway Wentworth State Forest, no plants present this year, however I am monitoring to ensure eradication.

Map 2 (note these data are also provided in Figures 2, 3 and 4)



Polygon;

- Road Reserve of 5, 7 and 46 to 73 Thiessen Crescent at Miena. Overall, some sites within the survey area have seen a significant reduction in Orange Hawkweed plants, however some sites have not. This may be due to the annual ongoing propagation of outlier plants on multiple land tenures.

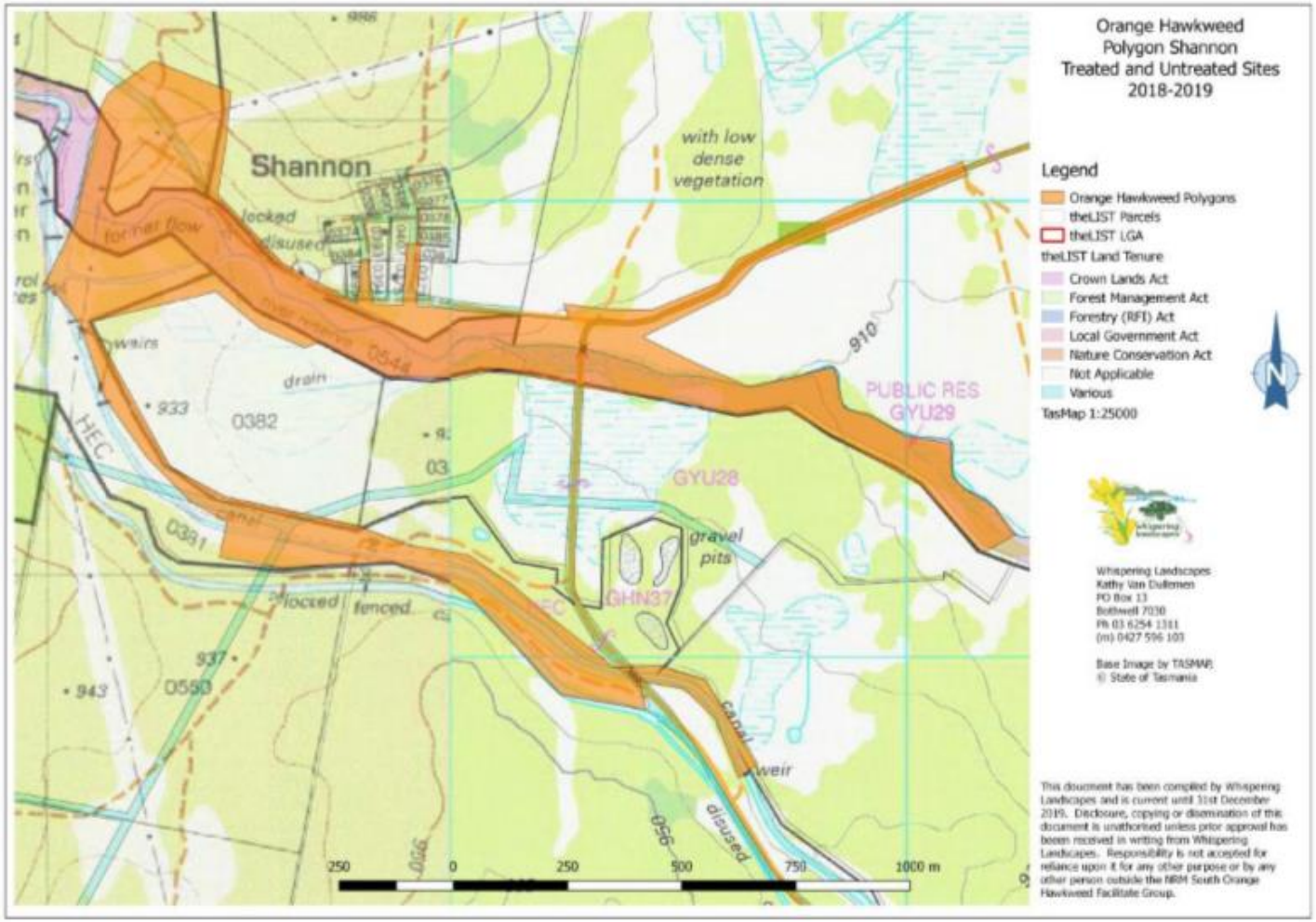
- Haddens Bay – Miena, Multi-land tenure site. This site has seen Orange Hawkweed plants numbers stay about the same, but their location changes significantly from year to year.

Point Data;

- Swan Bay, in the English Broom, a couple of plants present eight years ago, flowers picked, rosettes sprayed, and no plants have been seen since.

- Dud Bay, in the English Broom, a couple of plants present 4 years ago, flowers picked, rosettes sprayed, and no plants have been seen since.

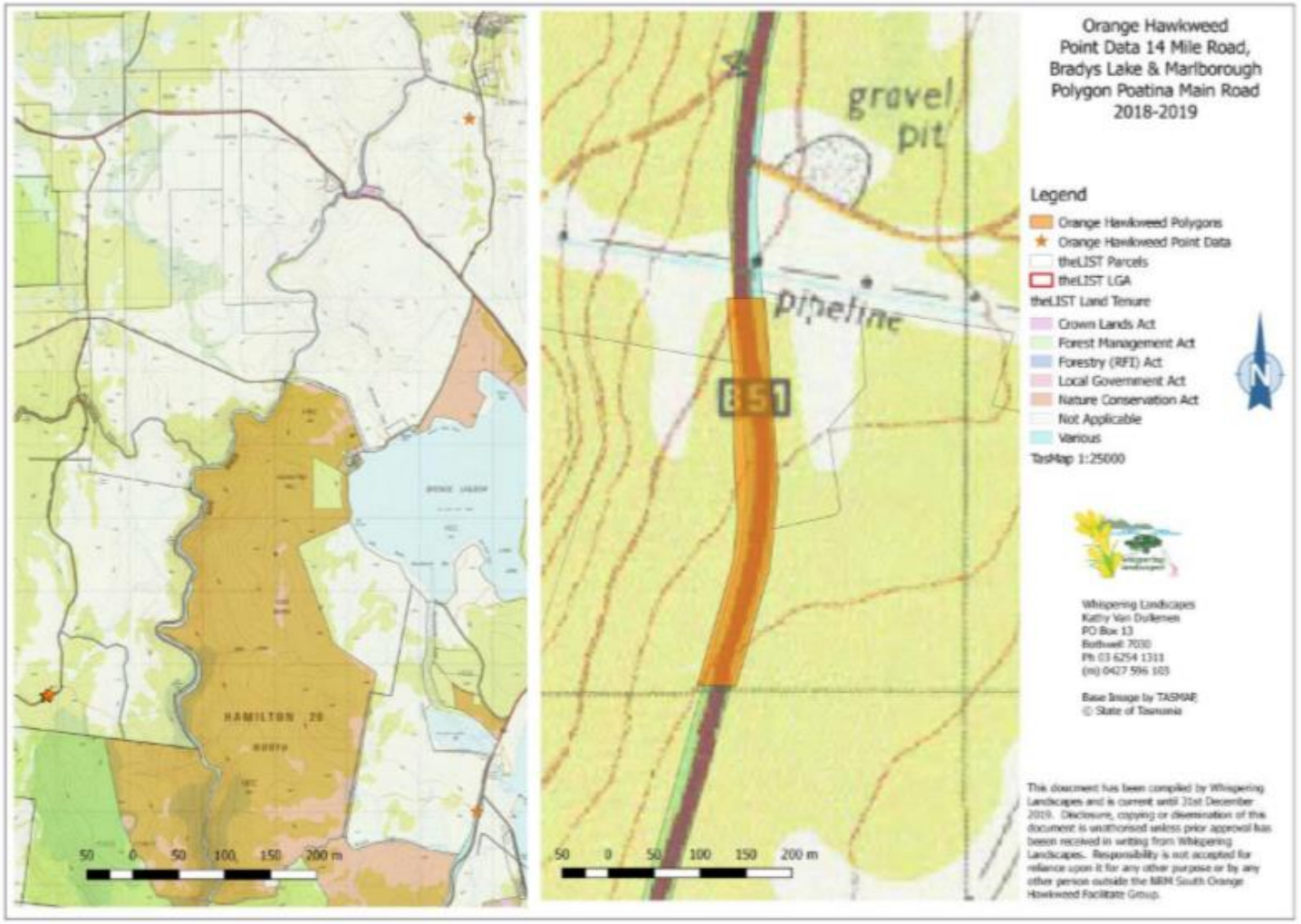
Map 3 (note these data are also provided in Figures 2, 3 and 4)



Polygon;

- Shannon, multi land tenure site. Over the 10 years of treatment, the dispersal of this plant across the landscapes has not reduced in size.
- It is most likely this site re-infects itself due to the naturally expanding area of plants that are not being treated.

Map 4 (note these data are also provided in Figures 2, 3 and 4)



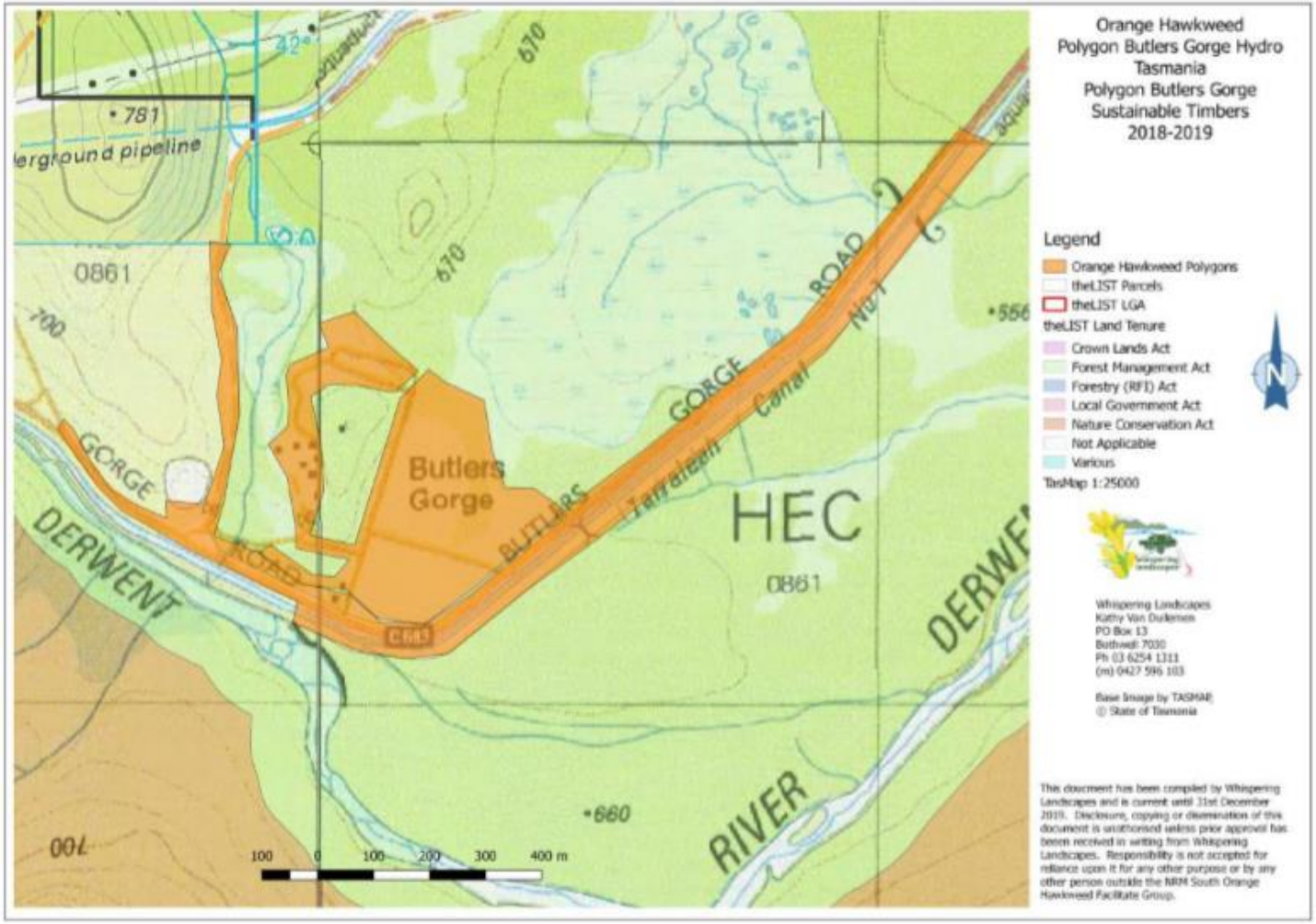
Point Data;

- Fourteen Mile Road, plants present population has reduced but varies from year to year.
- Lyell Highway near the Bradys Lake turn off, a couple of plants present seven years ago, road works removed the plants from the site, no plants have been seen since.
- Marlborough property off the Marlborough Road, no personal knowledge if subsequent survey and treatments have occurred.

Polygon;

- Poatina Main Road opposite Flintstones Water Treatment Plant. Significant reduction in infestation, 2017-18 season no plants sighted. 2018-19 season, 10 rosette clusters present.

Map 5 (note these data are also provided in Figures 2, 3 and 4)

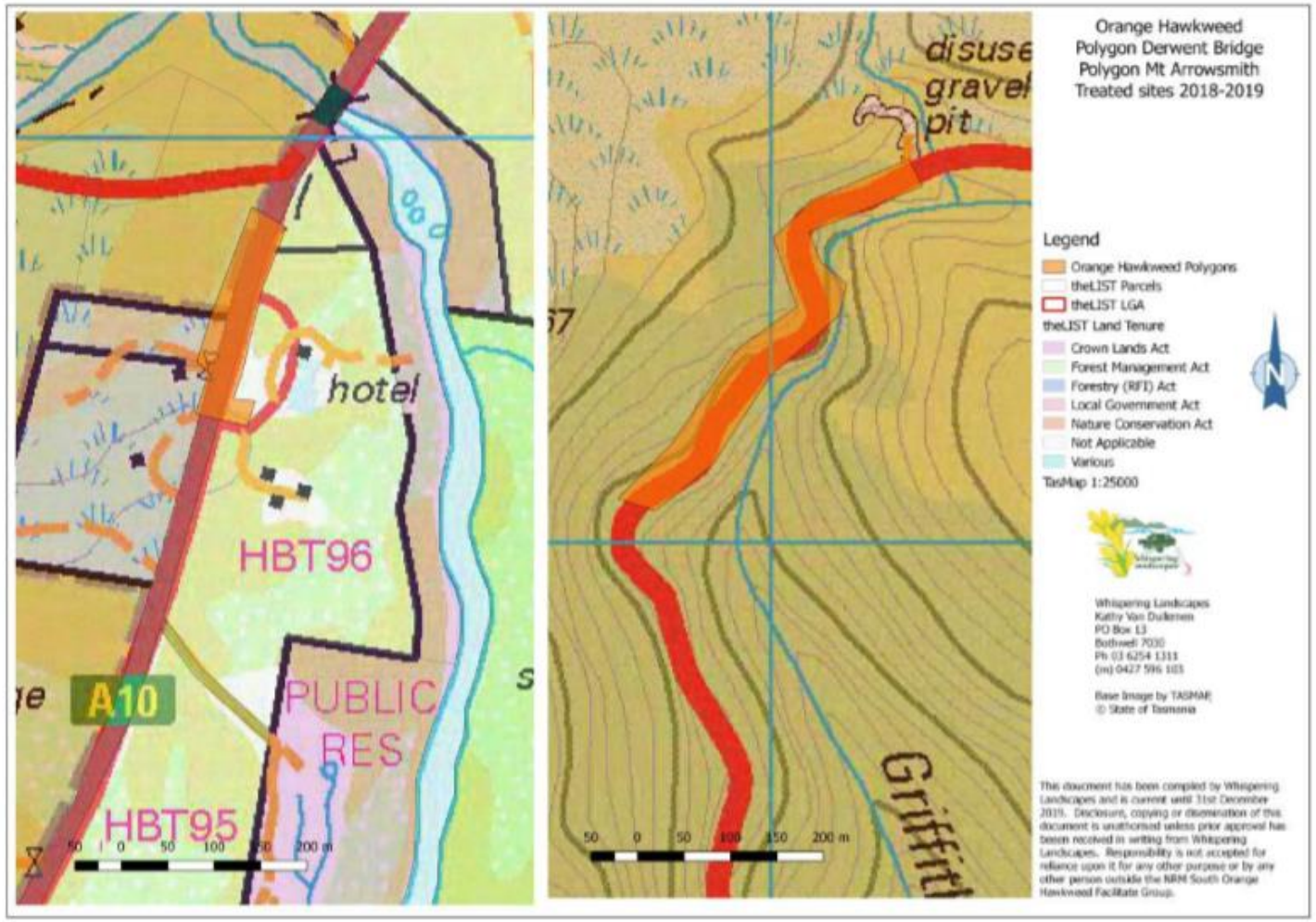


Polygon;

- Butlers Gorge Hydro Tasmania site consists of Butlers Gorge Road edges, canal edges and under wooden power poles. Overall a modest reduction in Orange Hawkweed plants is occurring due to effective and timely herbicide treatment.

- Butlers Gorge Sustainable Timbers land was surveyed initially by the Southern Councils Authority and treated by Whispering Landscapes. 2015-16 data delineates boundary of infestation. Site did contain upwards of 4000 plants.

Map 6 (note these data are also provided in Figures 2, 3 and 4)



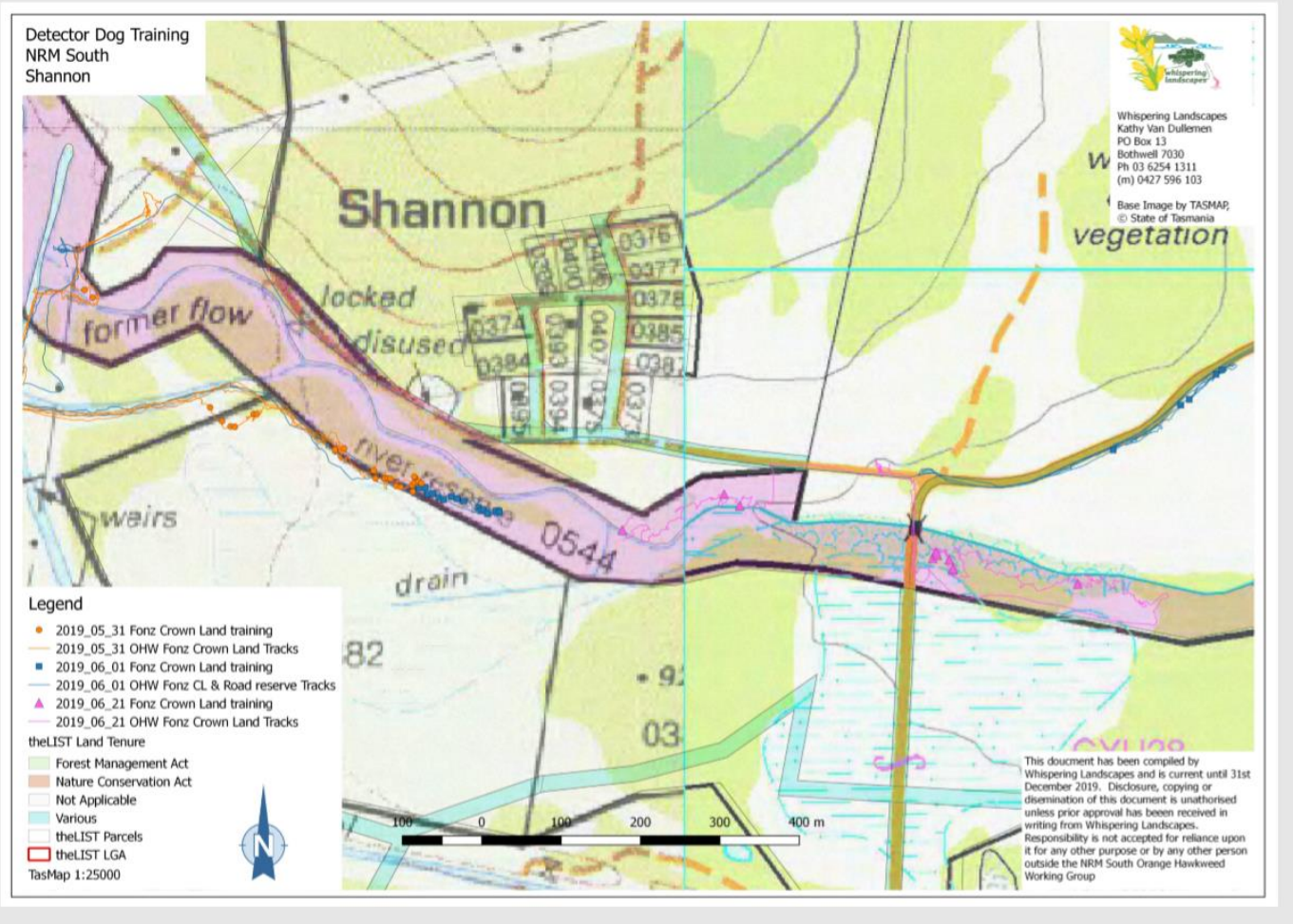
Polygon;

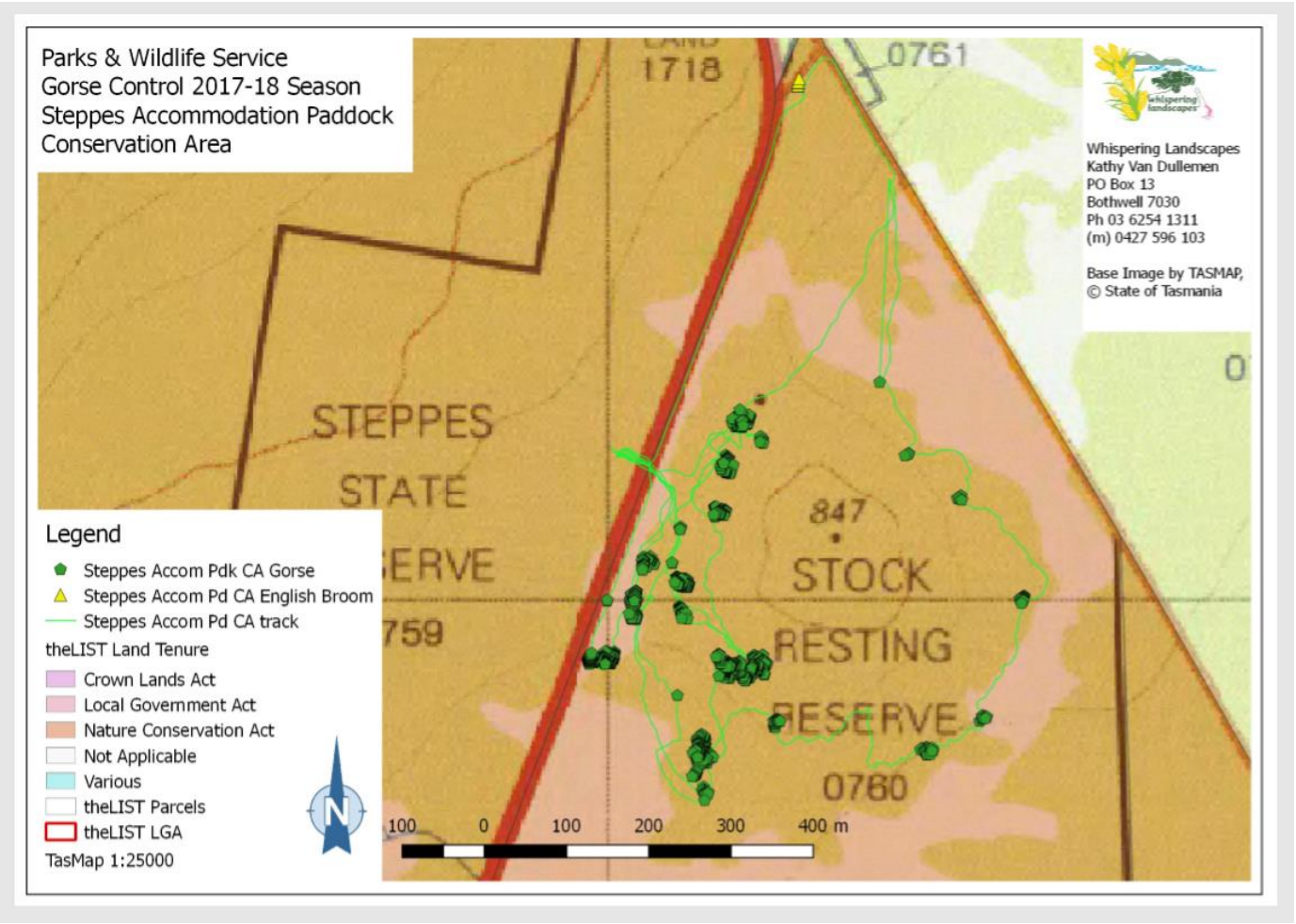
- Lyell Highway - Derwent Bridge. Multi-land tenure site, overall a significant reduction in Orange Hawkweed plants has been observed. Concern would be dispersal of plants from Derwent Bridge, as plants are located in areas used by the general public.
- Lyell Highway - Griffiths Creek - Mt Arrowsmith. Multi-land tenure site, overall a significant reduction in Orange Hawkweed plants has been observed.
- Lyell Highway – Squires Creek - Mt Arrowsmith, site surveyed multiple times, no plants present.
- Parks and Wildlife field staff have historically kept an eye on these areas.

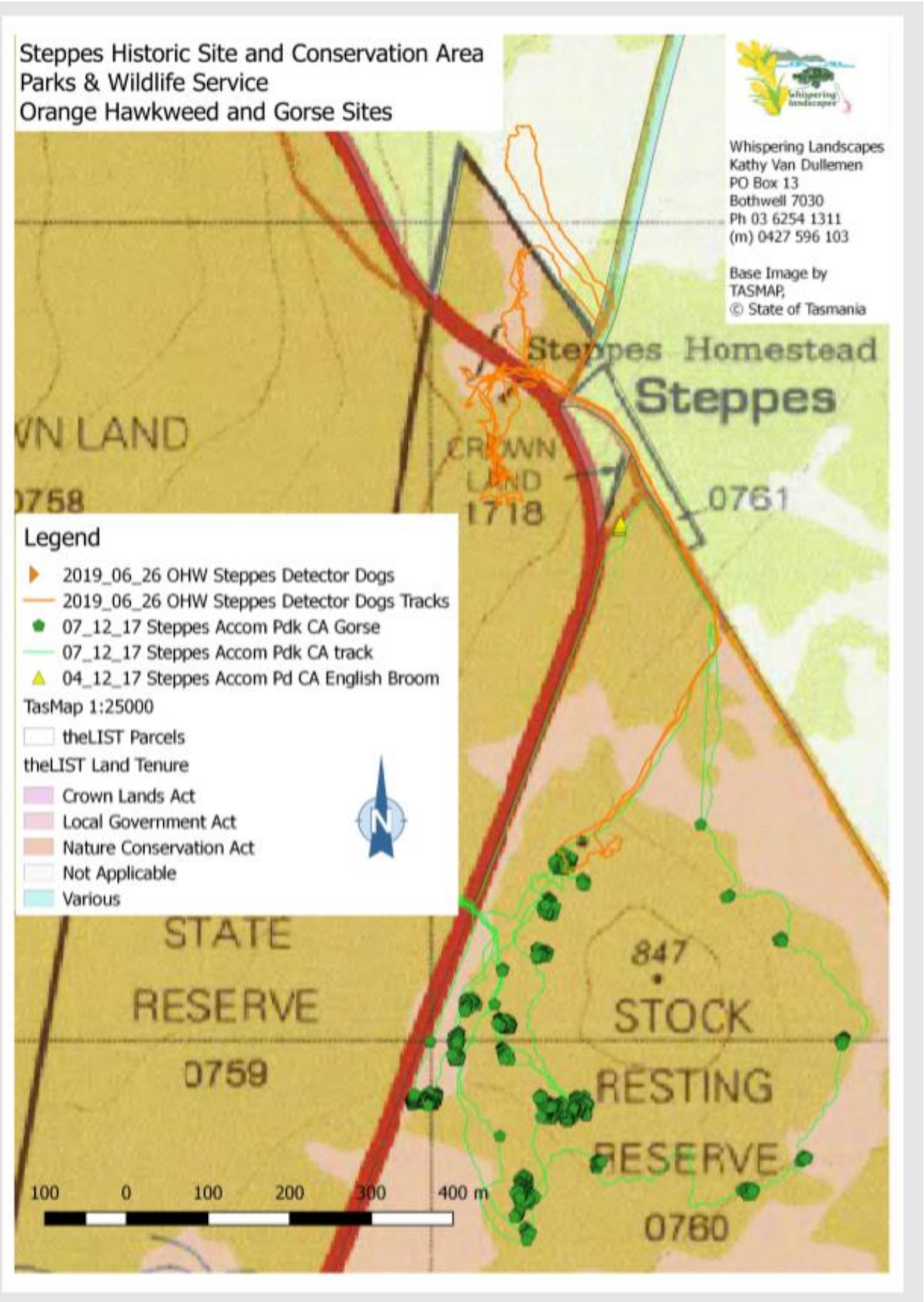
Appendix 2 Location of OHW at the Cattle Hill Wind Farm

Appendix 3 Maps showing Dog detector trials

Maps documenting the tracks of Fonz during work in the Central Highlands, provided by Whispering Landscapes




Parks & Wildlife Service
Gorse Control 2017-18 Season
Steppes Accommodation Paddock
Conservation Area
1718
0761
Whispering Landscapes
Kathy Van Dullemen
PO Box 13
Bothwell 7030
Ph 03 6254 1311
(m) 0427 596 103
Base Image by TASMAP,
© State of Tasmania
STEPPES
STATE
847
STOCK
RESTING
RESERVE
0760
759
Legend
Steppes Accom Pdk CA Gorse
Steppes Accom Pd CA English Broom
Steppes Accom Pd CA track
theLIST Land Tenure
Crown Lands Act
Local Government Act
Nature Conservation Act
Not Applicable
Various
theLIST Parcels
theLIST LGA
TasMap 1:25000
N
100 0 100 200 300 400 m


Steppes Historic Site and Conservation Area
Parks & Wildlife Service
Orange Hawkweed and Gorse Sites
Whispering Landscapes
Kathy Van Dullemen
PO Box 13
Bothwell 7030
Ph 03 6254 1311
(m) 0427 596 103
Base Image by
TASMAP,
© State of Tasmania
Steppes Homestead
Steppes
0761
1718
0758
Legend
2019_06_26 OHW Steppes Detector Dogs
2019_06_26 OHW Steppes Detector Dogs Tracks
07_12_17 Steppes Accom Pdk CA Gorse
07_12_17 Steppes Accom Pdk CA track
04_12_17 Steppes Accom Pd CA English Broom
TasMap 1:25000
theLIST Parcels
theLIST Land Tenure
Crown Lands Act
Local Government Act
Nature Conservation Act
Not Applicable
Various
N
STATE
RESERVE
0759
847
STOCK
RESTING
RESERVE
0760
100 0 100 200 300 400 m

Appendix 4 Modelling report Nick Beeton