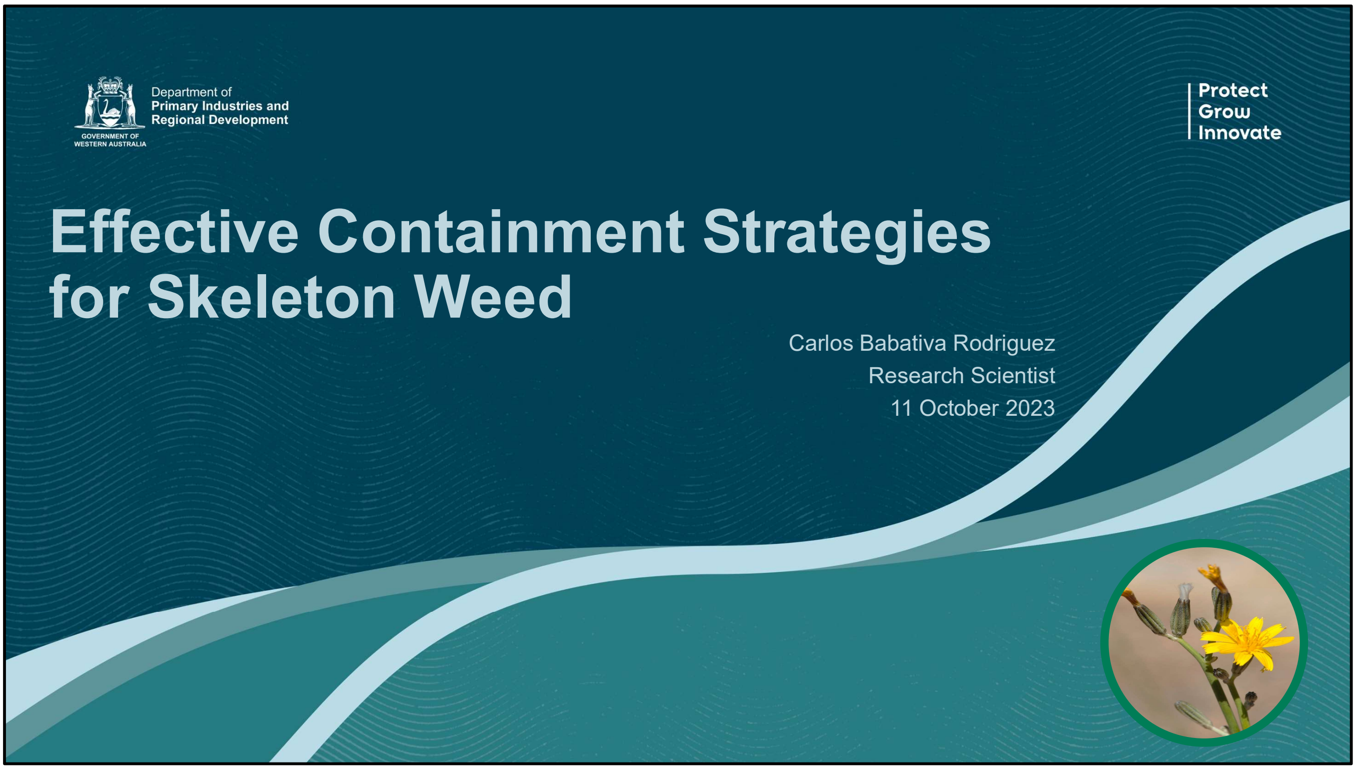
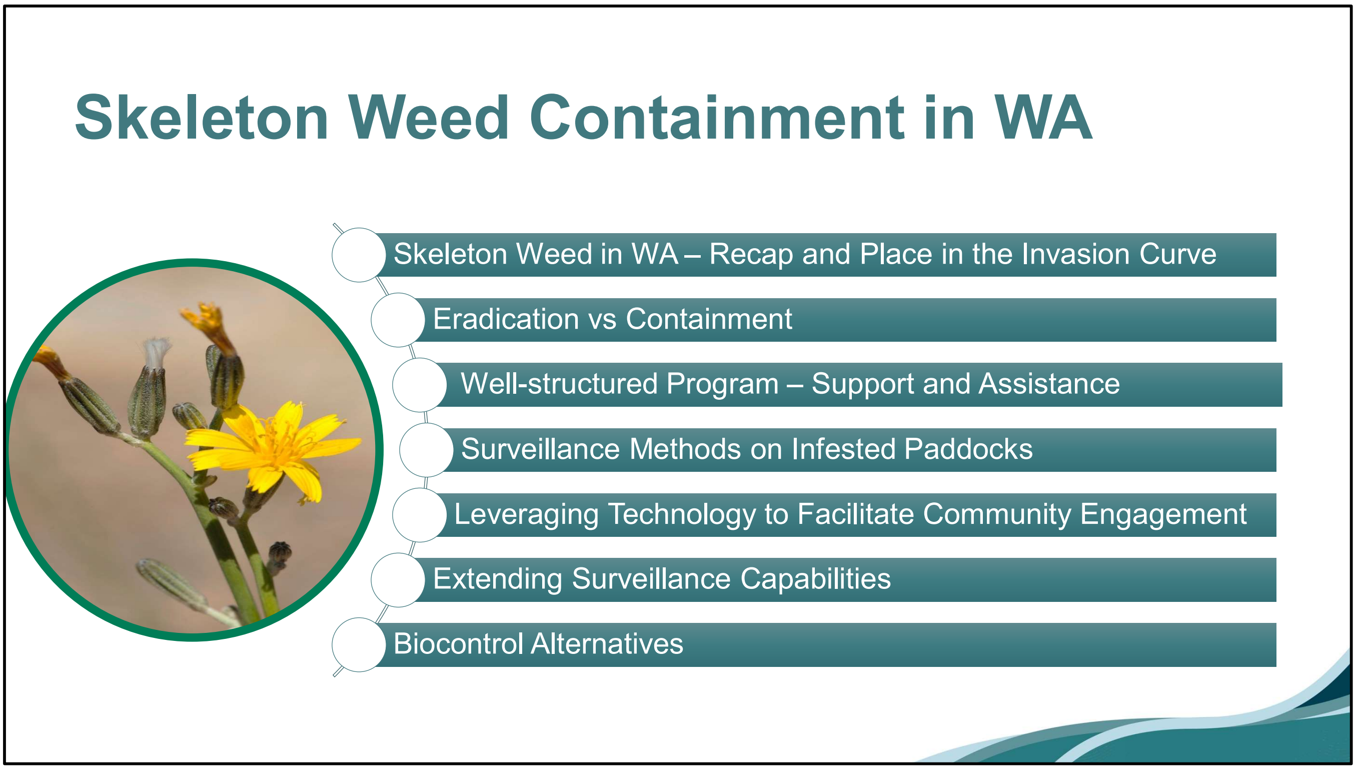


Good afternoon everyone, I will present on the amazing work that the Skeleton Weed Program has delivered in order to contain the infestation of an aggressively invasive weed wreaking havoc in the US, Canada, New Zealand, South Africa, Argentina, and even in our Aussie eastern states.

Skeleton weed grows an incredibly deep tap root typically 2 metres deep or more, which outcompetes other species for water availability. So much so that it can reduce wheat yield up to 80%, and it has the potential of nullifying pulse crops, due to their susceptibility to the same group herbicides that are most effective in controlling Skeleton Weed.

The current infestation in WA is at only 2% of its potential invasive power since its introduction some 60 years ago. This shows the importance of the suppressive capability of the program, where, in absence of it, an exponential expansion of the weed would have been expected.



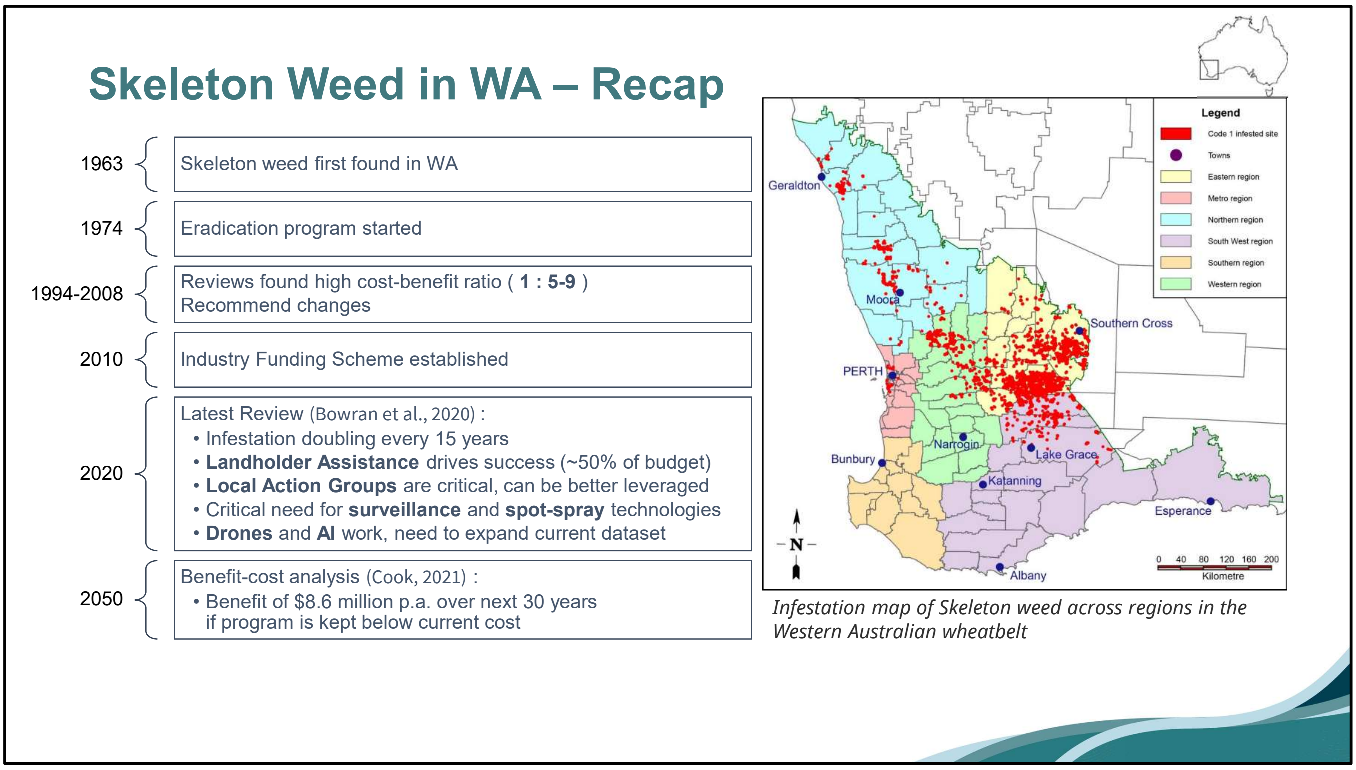
I will first run you through a recapitulation of what the Skeleton Weed program has looked like through the years;

Then I will show where the program sits in the context of the generalized invasion curve – which for this program, is a bit of a spectrum… So I will reveal the facts that for why this occurs. That is, where eradication takes prevalence vs containment.

Then I will provide a snapshot of what the different fronts that the program features which compose the strategies for successful containment

Following that, I will provide in-a-nutshell snapshots of some of the strategies used in the program as well as some innovative solutions that aim at optimizing the efficiency of the program by leveraging modern technology integrations.

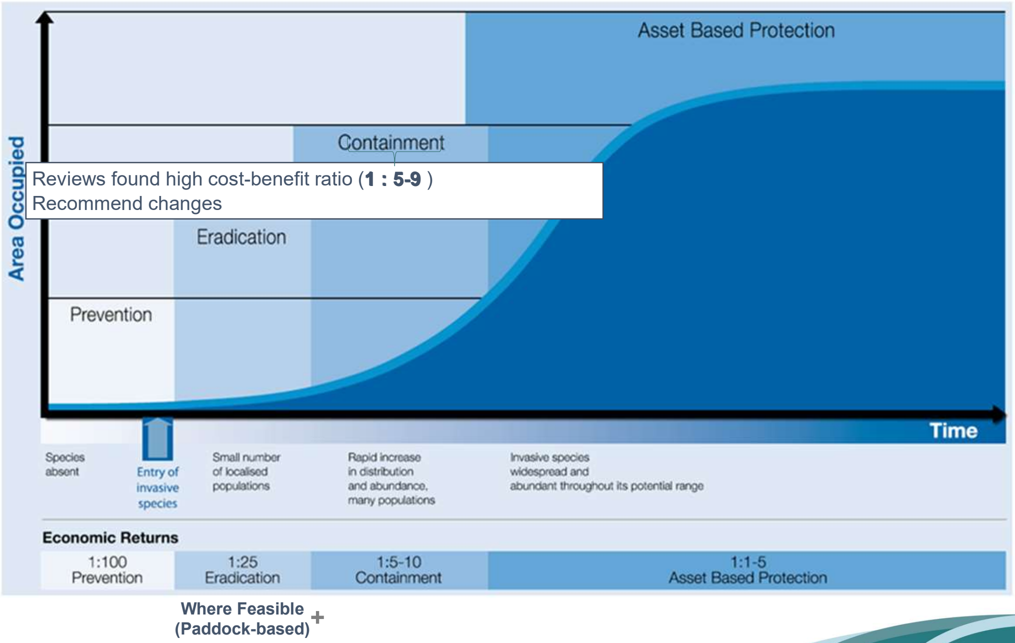
Lastly, I will give an insight into some initiatives currently raising up on the horizon, which also aim at raising the capability with opportunistic and leading-edge methods which can be extended to other invasive species.



- First found in WA in 1963
- Eradication Program started in 1974
- 3 major reviews found that the cost-benefit ratio was between 5 and 9 to 1
  - However, recommendations were made to find break-even point and reshape the program to involve landholders in control to achieve cost-effective control
- Current aim of the IFS-funded program is "*to prevent seed-set and movement of skeleton weed and paddock-based eradication where feasible*".
- The latest Program Review in 2020 (Bowran et al., 2020) found that:
  - *"Infestation is being contained, but it's still doubling every 14-15 years"*
  - *"Successful extirpation largely due to [strategic] incentivized on-farm searches performed by contractors and farmers at about half of the program's budget."*
  - "Lack of ability to detect and **spot spray** skeleton weed is considered a critical issue, but technology is rapidly expanding and worthy of research"
  - *"New surveillance technologies to identify new infestations will be critical to finding plants before infestations spread seeds widely."*

    - *…Where "An area of 1.8 million hectares would need to be surveyed to understand the full extent of skeleton weed presence in WA"*
    - *…And while "Investment has been seen in drone (UAV) technology and neural networks software capable of identifying skeleton weed in WA"*
    - *"A much larger image dataset is required"*
- Benefit-cost analysis (Cook, 2021)
    - Total benefit of $8.6 million pa over 30 years
    - It is highlighted that the program might hit a trend towards reaching break-even point

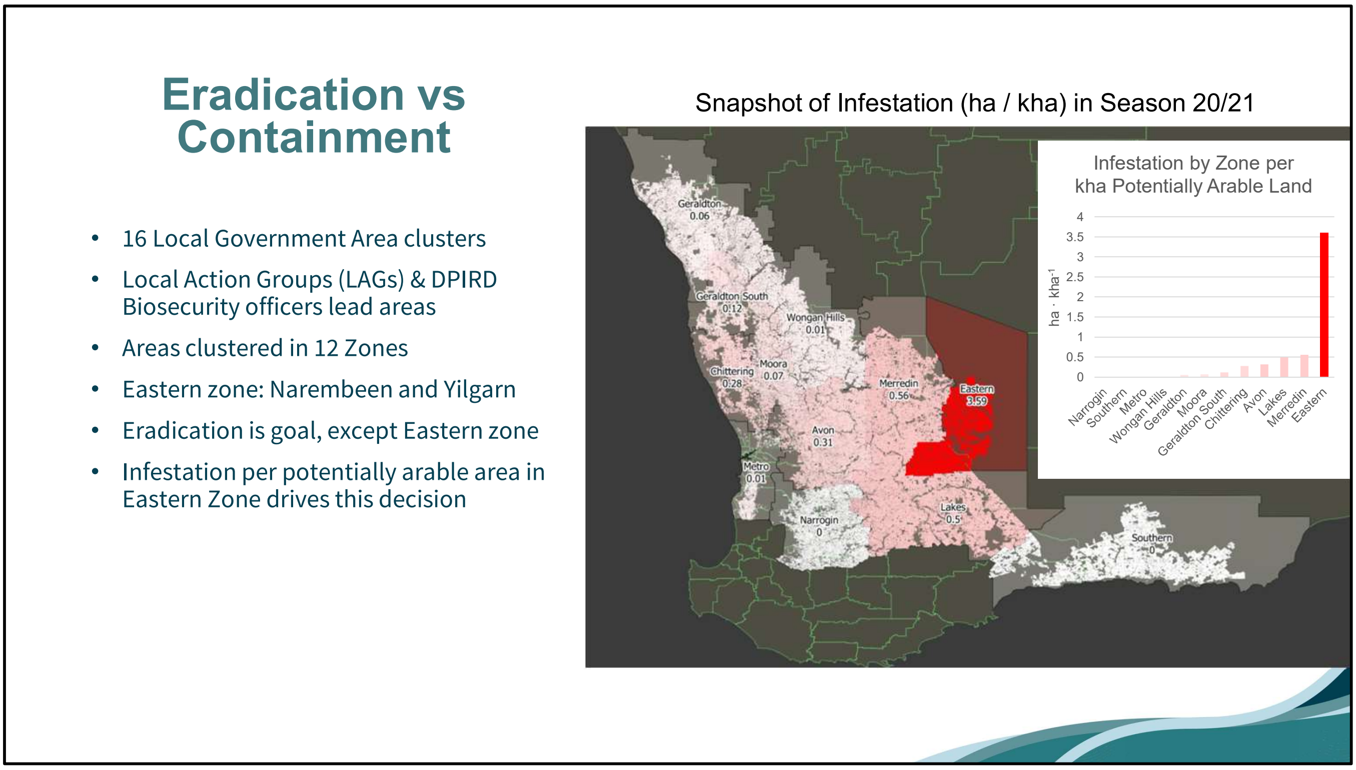
Skeleton Weed in the Invasion Curve



So if we look at the context of the generalized invasive curve, the cost benefit of the program places it at the Containment level. However, there is a significant difference in levels of infestation depending on where in the wheatbelt you're standing.

For that reason, the program effectively aims at paddock-level eradication of the weed wherever it is feasible, as it is a much more beneficial approach as opposed to completely taking the foot off the pedal and hoping to get on top of it via asset-based management.
Growers are actively involved via monetised searching incentives in order to achieve this.

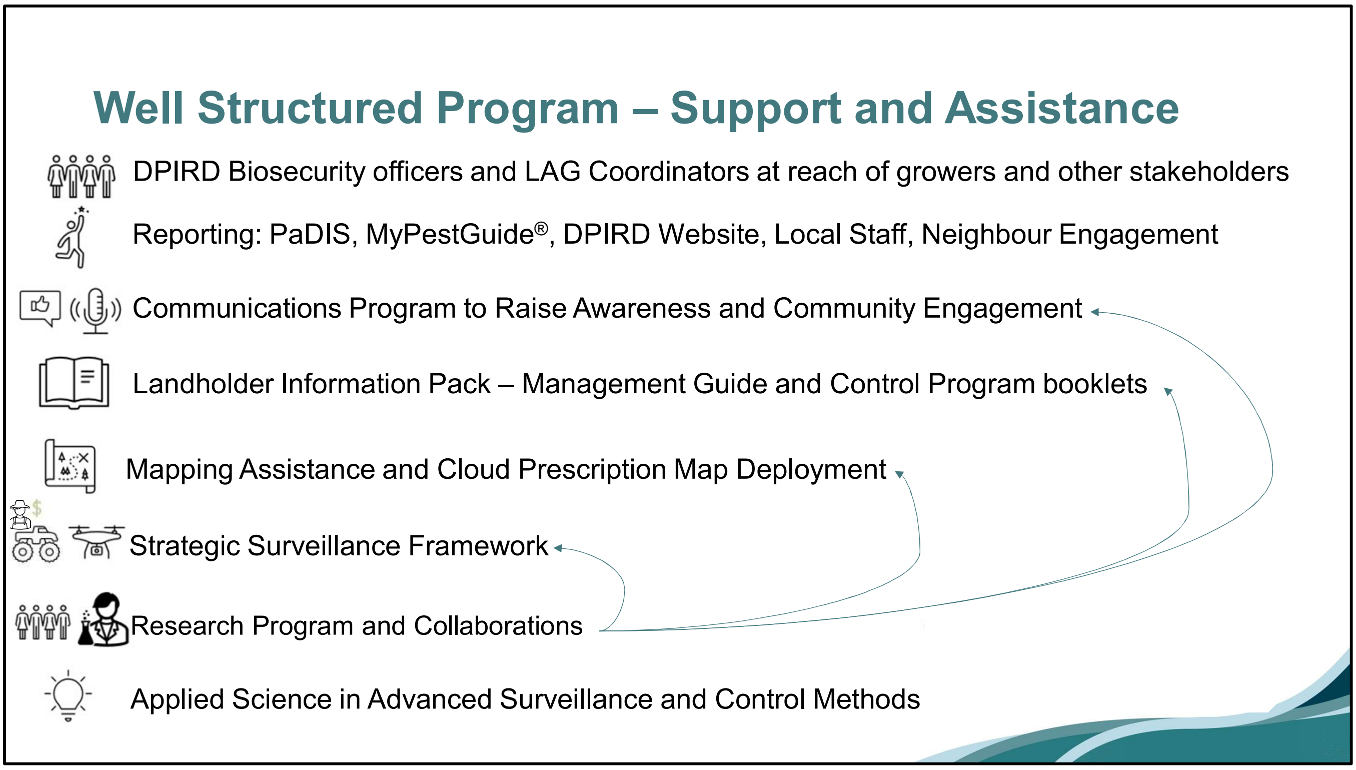
This is what the program review highlighted as highly successful.



So we will have a look at where the program is most benefitable from eradication. But first, let me tell you where the program operates and how bad an infestation we have at these places.

- The program operates on 16 LGA clusters comprising the Western Australian wheatbelt
- Management lead by Local Action Group (LAG) coordinators (where available) and DPIRD Biosecurity officers
- Areas are clustered in 12 Zones
- LGAs of Narembeen and Yilgarn conform the Eastern zone
- The goal is Eradication in all zones, except the Eastern zone
- Infestation per potentially arable area in Eastern Zone drives this decision

As such, under the Biosecurity and Agriculture Management Act, Skeleton Weed is declared as a Category C2 in the Easter States, and a Category C3 everywhere else in the state. This elicits growers to manage the weed accordingly, for which the industry-funded program provides ample support and assistance



Over the years, the program has consolidated into a very well-structured machinery where landholders are not alone in their efforts towards extirpating the weed from their properties.

The operational staff of the program, coordinators of recognised Local Action Groups alongside DPIRD biosecurity officers are deeply engaged with growers and the broader community as well as other relevant stakeholders like other government agencies or landholders of diverse tenure systems.
They act as the main point of contact for advice and support, and deliver the tasks set out by the program on the ground. They are the pumping heart of the program and I give a shout out to them in their endeavours.

The program has also been set up to allow diverse channels of reporting the weed as well as plenty of audiovisual communications aiming at raising the awareness in the community, encourage prompt reporting, and remind landholders of their shared responsibility and compliance obligations, highlighting the support available and the advantages of success.

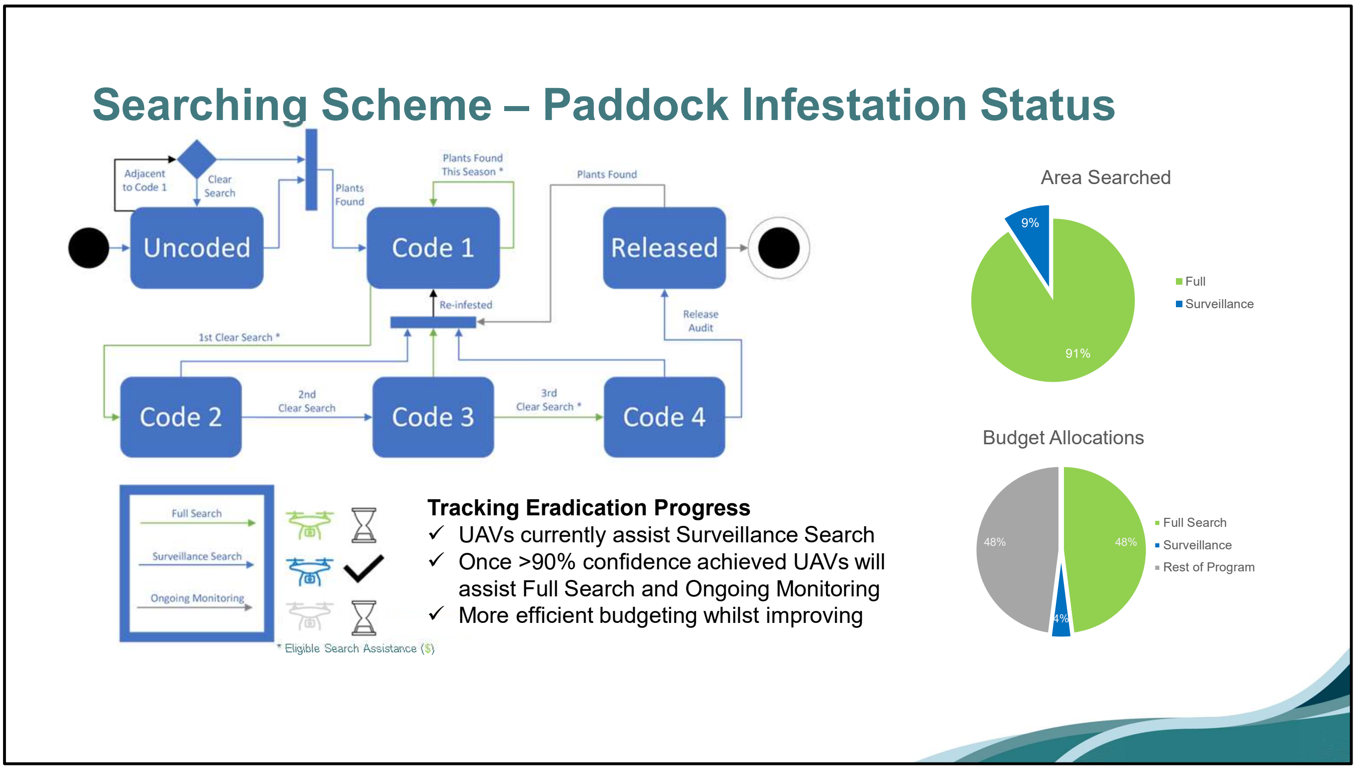
All of this information is neatly packed up in a landholder information pack distributed during general annual grower meetings and other gatherings, effectively expanding the footprint of the program. Two yearly revised booklets provide landholders with the latest available necessary for successfully managing the weed, plus plenty of material for identifying the plant correctly.

The data collection and utilisation infrastructure of the program, backed by DPIRD's enterprise GIS solution is the meat and bones of the program. There are some 10,000 hectares of infestation mapped annually with tablets working on differential GPS for metre-precision location of the infestations. All this accurate mapping effort is collectively built by the program operators (LAGs and Biosecurity officers) as well as weeding control and searching contractors.

This strong data infrastructure has allowed for the design of a strategic surveillance framework that effectively tracks the progress paddock-level extirpation of the weed, which I will briefly describe further on.

Since the establishment of the Research Program as a result of the 2020 program review, the recommendations highlighted earlier have been addressed in order to potentiate the current capability of the program, as well as explore or expand innovative methods of operations, surveillance and control, majorly catalysed and oversought by Senior Research Scientist John Moore.

This is why we have been strongly involving CSIRO in collaboration for the development and deployment of some of these methods.

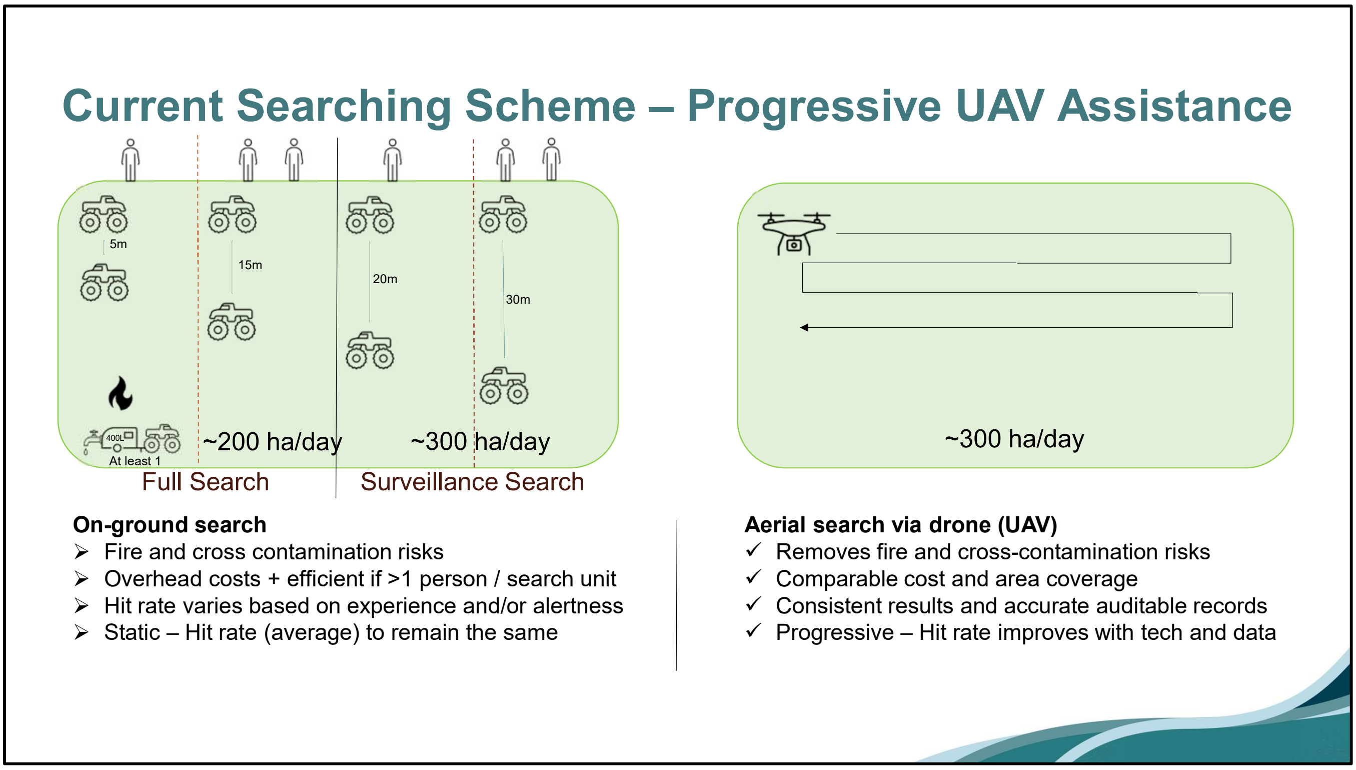


Each search method is employed at a different stage of the paddock infestation coding scheme, where paddocks progress every year with clear searches until being released from the infested list.

* The aim of this process is to assist farmers in achieving the goal of eradication, whilst maintaining as many of their paddocks clean which in turn allows them to maximise their profit.

* Currently, drones assist with Surveillance searches, which account for about * a tenth of the area searched by the program, and only about * 4% of the program's budget.

Once 90% confidence is achieved by drones, * this technology could start assisting Full search and Ongoing Monitoring operations, which should lower the operations' cost; and steering away from the break-even point in cost-benefit.

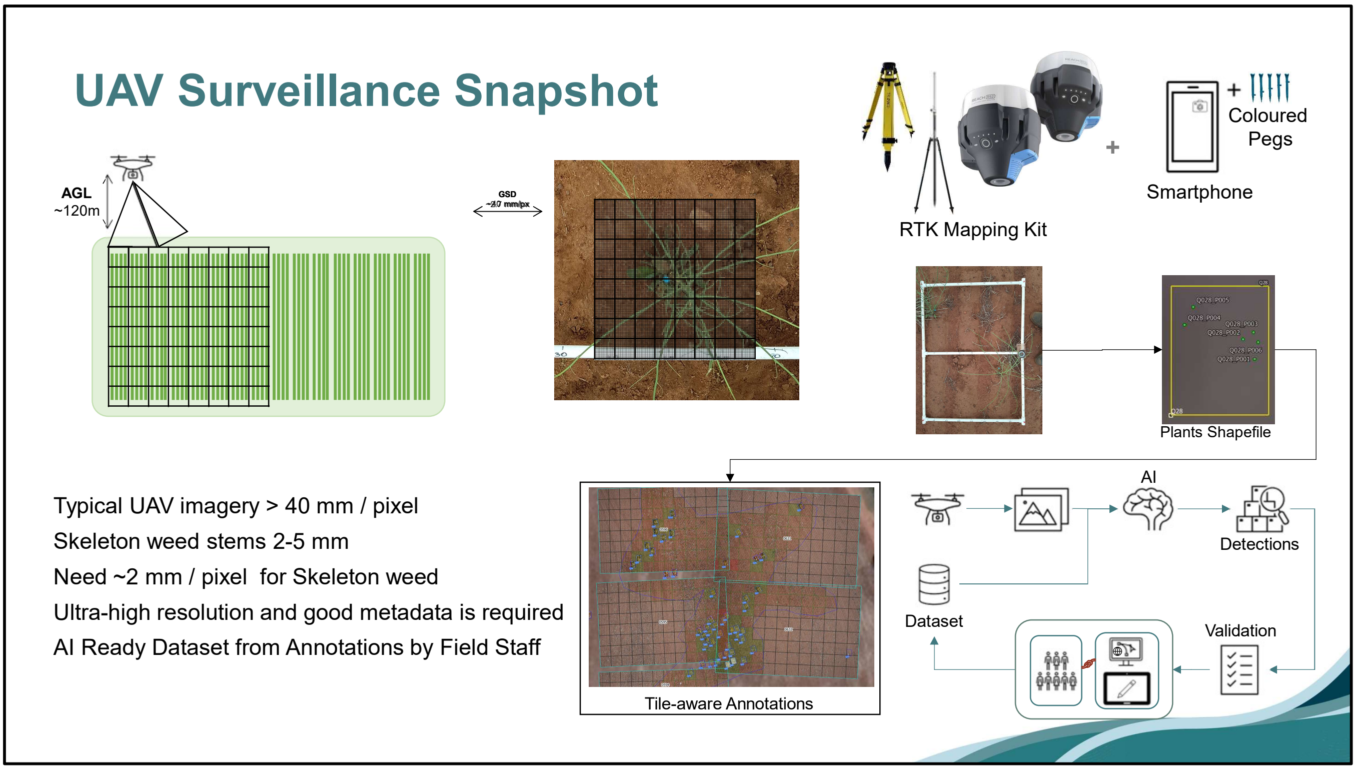


The current searching scheme consists of full search and surveillance search. Surveillance searches are aimed to delimit the infestation areas, so landholders are to perform full search as soon as a plant is found, and further surveillance is undertaken on adjacent paddocks.
Due to the risk of starting a fire, at least one of the vehicles must be equipped with fire-fighting equipment and at least 400L of water.

The typical coverage of surveillance for full search is about 200 ha per day with two spotters in a search unit and about 300 ha per day for surveillance search operations.

* At this stage, drones can match the efficiency of surveillance search operations at around 300ha per day and around the same cost per hectare also.

* There are several advantages of Aerial surveillance in comparison to ground-based operations during summer:
- The risk of fire is significantly reduced
- There are no overhead operational costs or efficiency loss with experienced staff turn-over
- Hit rate accuracy remains consistent and auditable imagery records are kept
- And the performance is expected to improves along with data and technology



The 2020 Program Review highlighted the importance of *New surveillance technologies to identify new infestations*
And the need for *A much larger image dataset*

We have collected sufficient ground truth data alongside drone imagery to create an object detection model which can now be used to expand the current dataset by harvesting and validating skeleton weed detections.

Here I present the challenges encountered and current approach to achieving a larger and efficient dataset.

* Typical broadacre agriculture drone operations are satisfied at a GSD of 1cm+ per pixel for things like a simple Overview of the crop, or measurements of Ground cover or Chorophyl content estimates
Even some weed detection operations work at that coarser level of resolution for weeds that usually have abundant foliage or flowers.

Skeleton Weed is much trickier to detect. It lacks foliage; its stems range from 2 – 5mm for a mid- to mature plant * ; and is typically found as individual satellite plants or sparse clusters of them.

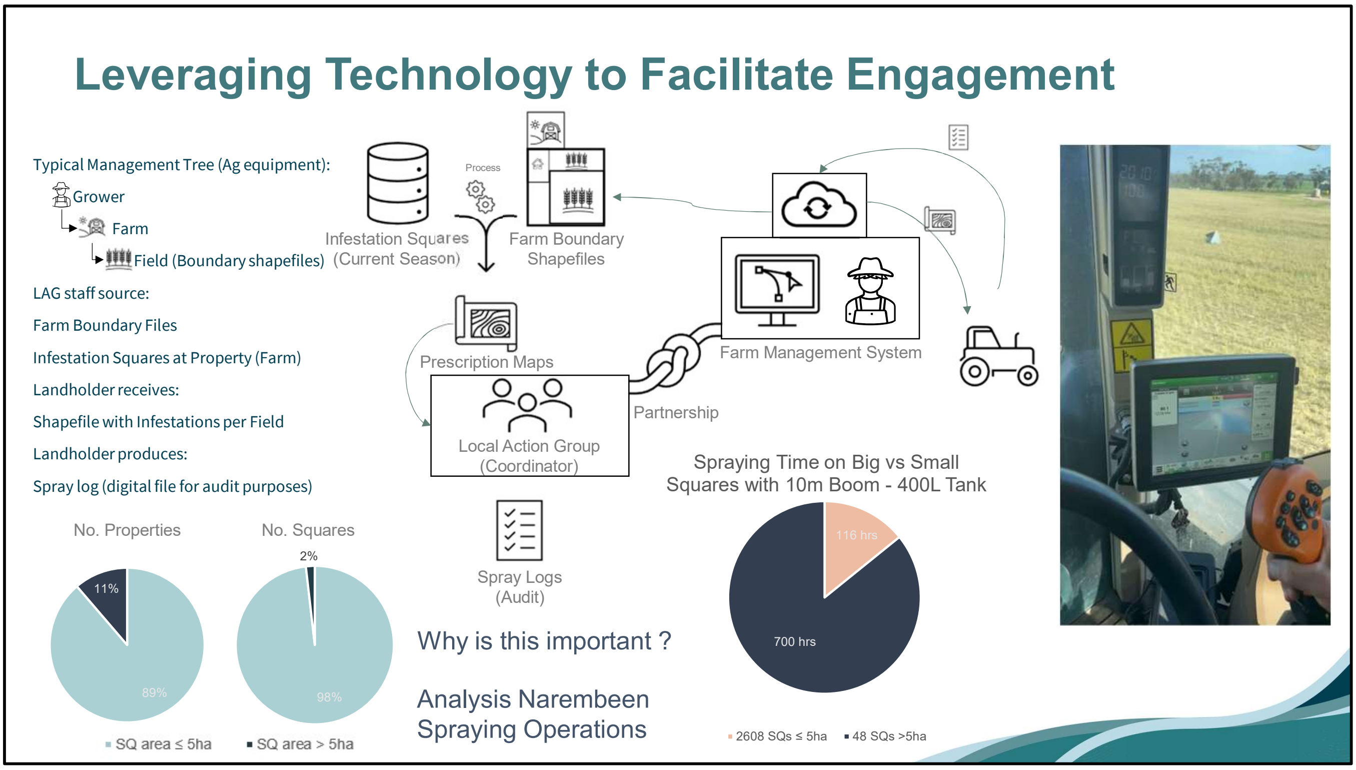
* If we were to try detecting the plants at that resolution, the stems would be blurred out.

* So a much finer resolution is required to detect the plants, and train an AI model successfully.

* Apart from that, we faced some consistency issues that more modern cameras would help us alleviate.
* Plug-and-play cameras, Unfortunately, did not provide fine enough GSD to match the on-ground surveillance coverage per day at a comparable cost.
The downside of using a * DSLR Camera was the required integration of gimbal and a GPS marker with time-based captures was required.
* This setup also accounted for a lack of ability to record flight metadata, and a requirement for data post-processing.

So the eventual workflow to achieve a better dataset to train a more confident and efficient model looks like this:

We capture the surveillance with some ground truth imagery, allow the current model to perform detections, these need to be validated by the people that are most ***confident*** in distinguishing the plant, and that very likely has been standing next to it while mapping it. This process needs to be intuitive and efficient, which is also what we're starting to work on with the department's GIS group and enterprise solution, based on the way we built the original dataset.

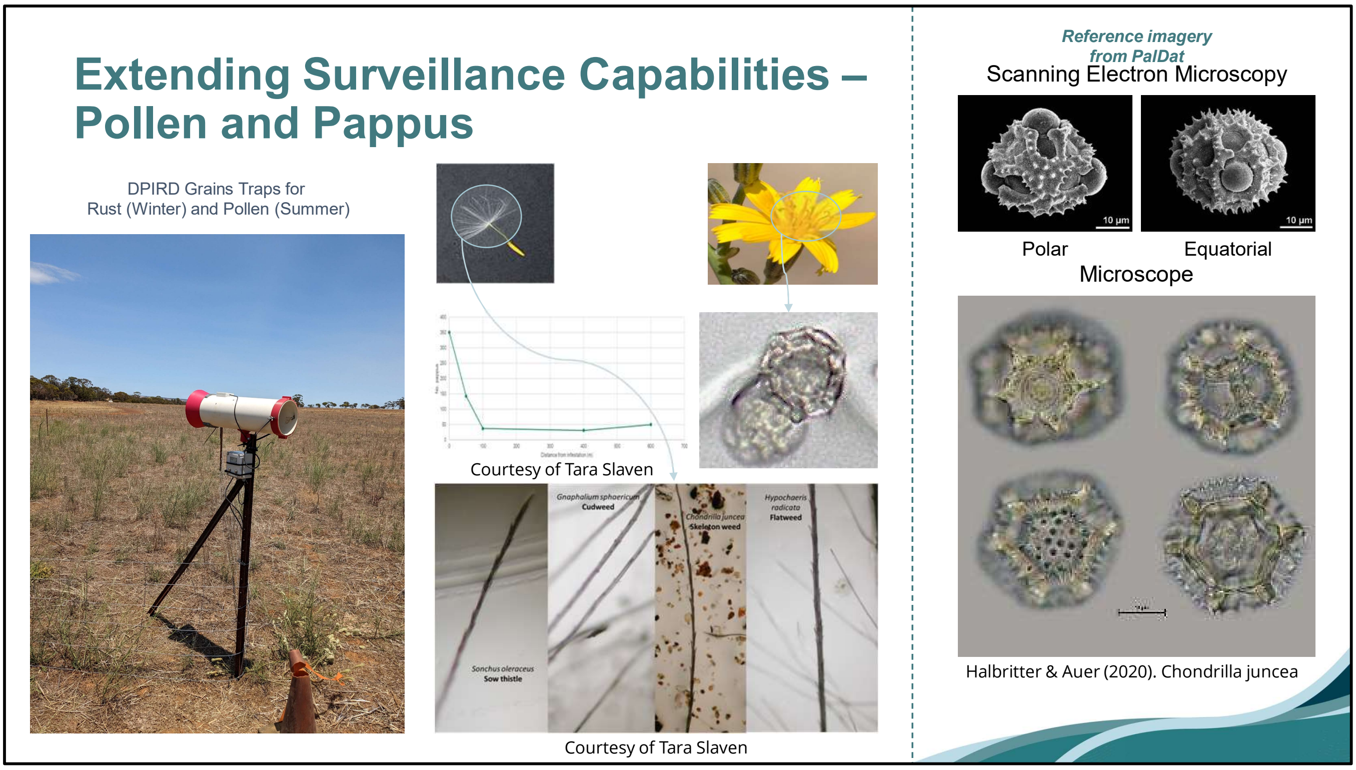


The 2020 Program Review also highlighted that the "Lack of ability to detect and **spot spray** skeleton weed is considered a critical issue, but technology is rapidly expanding and worthy of research" And that "*The very large database on skeleton weed across the south west is a valuable resource but is heavily underutilized"*

Based on those observations, amplified by the frustration of LAG coordinators in the Eastern areas when controlling large infestation squares (over 5ha) in the absence of a method to deploy digital maps to farmers for controlling their infestations, We looked into and implemented a framework to deploy prescription maps over the cloud directly to farmers auto spray machinery.

After analysing data from Narembeen, it was estimated that the effort put into spraying around 50 big squares was much larger than that of spraying more than 2500 smaller – typical-size infestation squares.

In fact, it was estimated that with a 10-metre boom, 700 hours would be spent on 50 big squares as compared to 120 for the 2500 smaller squares.



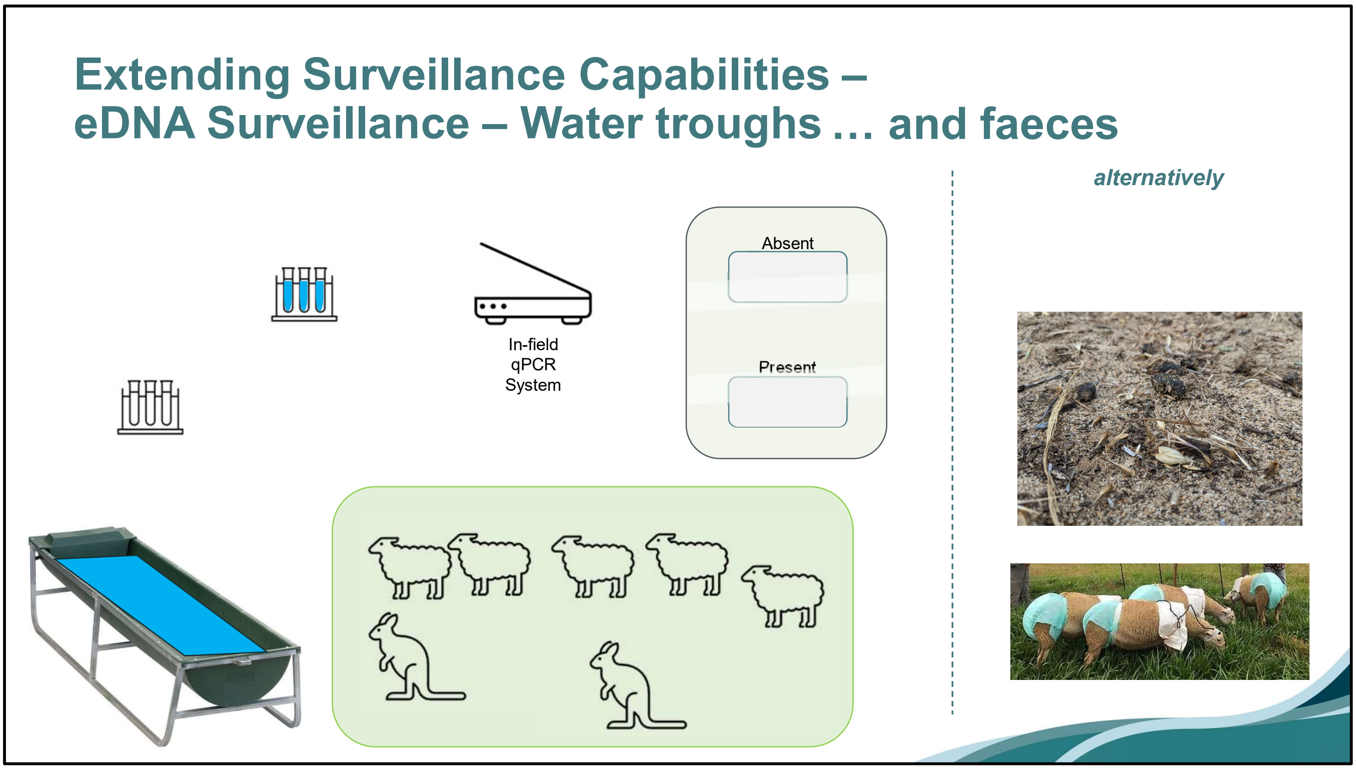
In terms of extending the current surveillance program, an opportunistic approach was taken to utilize rust monitoring devices used across the wheatbelt during winter to perform passive surveillance on skeleton weed pollen.

This is some reference imagery of what Skeleton Weed pollen looks like.

We sampled some pollen onto a microscope slide and we got some good reference imagery of pollen at 100 times magnification.

However, we found that Skeleton Weed seed pappus is more prevalent when sampled in the vicinity of infestations.

With traps placed up to 650 metres away form a small 15 by 15 metres infestation, we were still picking up pappus fractions on the slides.



In collaboration with CSIRO, we are also currently looking into the possibility of utilizing Environmental DNA (eDNA) sampling in order to assess paddock-level presence or absence of the weed.

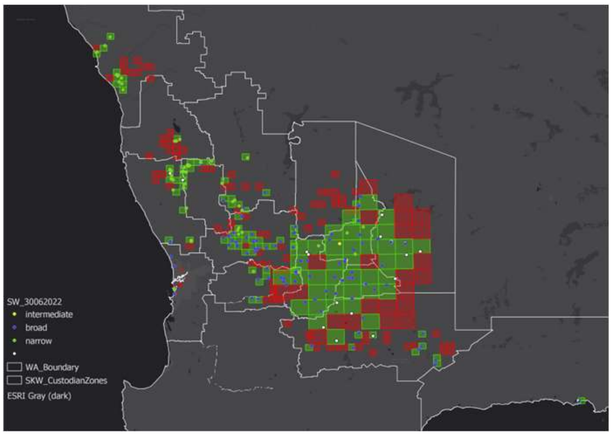
This representation is not necessarily an precise representation of what the final solution would look like, but it does capture and convey the main principle to be achieved – instantaneous in-field decision making about whether to search paddocks for skeleton weed.

Water is sampled from a drinking trough, given that both livestock and kangaroos feed on Skeleton weed stems; process the samples to amplify any Skeleton weed DNA present in the sampled water, and get an in-field assessment.

Alternatively, faeces in the field could also be sampled to determine the presence of the weed.

Biocontrol on Skeleton Weed – Biotype Survey

- Set up surveying grid – integrated in Collector/Field Maps
  - 195 Samples Collected
  - 173 Unique submissions.



Skeleton Weed Biotypes in WA:

- Narrow leaf
  - Highly prevalent along the coastline, but also present further inland
- Broad leaf
  - Highly prevalent on the eastern/ southern infestations, but also present along the coastline and Metro
- Intermediate
  - Present, but in very low numbers

Biocontrol is always an attractive alternative for containing invasive species with great invasive potential. Skeleton weed is not the exception, especially when some biocontrol agents have already been successfully established over east and perform a reasonable contribution towards containment.

During the last couple of years a two stage approach has been taken to deploy biocontrol agents not yet present in WA.

About 200 samples were processed to find that Narrow leaf and Broad leaf forms are most prevalent along the coast and inland respectively, whereas the Intermediate form is quite scarce.
We performed a survey of Skeleton Weed Biotype to delineate the extension of each biotype. The map shown demonstrates the approach taken, where heavily infested areas were sampled at a large grid cell-size, medium cell size was used for sparse infestations, and much smaller areas for metro area. This aims to adjust to the expected biotype diversity in the landscape

Biocontrol on Skeleton Weed – Alternatives

Skeleton Weed Rust - *Puccinia chondrillina*

Courtesy of Kate Detchon

Skeleton Weed Gall Midge - *Cystiphora schmidti*

Courtesy of Mick Davy (CSIRO)

The current alternatives being looked at for biocontrol include mainly the Skeleton weed rust and the Skeleton Weed Gall Midge.

The rust was introduced a few decades ago and has managed to establish itself around the Moora area. Although it does a magnificent job at depleting the invasive power of the weed, it is also only effective against narrow and intermediate leaf form.

On the other hand, the gall midge does affect broad-leaf form. For that reason, a current rearing program is running to establish the midge across the wheatbelt, by targeting refuge zones where typical control of the weed is very little practical.

A massive body of work has been led and undertaken by Senior Technical Officer Kate Detchon and continuous support from Mick Davy and I give them a shout out for their efforts.

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Paul Manera – Skeleton Weed Operations Manager
DPIRD Senior Biosecurity Officer

Skeleton Weed Operational Team – Continuous Support
Biosecurity officers and LAG Coordinators

CSIRO Team – Gavin Hunter, Mariana Campos, Kathryn Batchelor, Karen Bell, Mick Davy, Bruce Webber, and Sharon van Brunschot
Collaboration on Advanced Surveillance and Control methods

So that’s all for now, I hope you have enjoyed the few bits of information that I’ve left a few bits out of this presentation, and I’ve also shared with you today about the program, and I want to acknowledge the peers on the screen who have done a fantastic job towards the success of the program

Is there any questions ?

Thank you

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