Siam weed and the Dust Devils. Managing *Chromolaena odorata* in the Northern Territory

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Summary Chromolaena (*Chromolaena odorata*) was discovered for the first time in the Northern Territory in 2019. Apart from two small roadside outliers, the following two years of survey found all plants within ~10km from 'ground zero'. If this remained all that was present in the NT the case for eradication was considered ambitious, but feasible.

Delimitation of a weed in the landscape is key to eradication. Debate ensued on the best allocation of limited survey resource to do so.

Four weeks of helicopter survey took place in July 2021, crossing five major river catchments across approximately 9,500 km^2. The results of the survey changed the direction of management in the NT. Eradication was now deemed unachievable.

Locations of new infestations, many in areas unrelated to infrastructure or animal tracks, can only be attributed to long-distance spread by wind.

The survey results underpin the new reality of managing chromolaena in the Northern Territory. Focus has shifted from an in-house eradication program to land holder extension; with a view to containment, early intervention of new infestations and mitigation of spread. Effort is being channeled into control research and remote survey techniques, ultimately providing best practice tools for management applicable to the Northern Australian savanna.

Keywords Eradication, Chromolaena odorata, Siam weed, Remote sensing, Dust Devils

THE PREMIER WEED THREAT TO NORTHERN AUSTRALIA

'***You might have gamba and mimosa, but at least you don't have Siam weed'***- was a phrase used to warn Northern Territory (NT) weed managers by 'those in the know'; Land managers, scientists and researchers familiar with chromolaena in Asia and Northern Queensland.

Commonly known as Siam weed, chromolaena (*Chromolaena odorata* (L.) R.M. King & H. Rob) is widely regarded as one of the world's worst tropical weed species. It grows as a 3-4 metre tall sprawling shrub that forms dense, entwined thickets. If supported, chromolaena's scrambling branches can climb to 20 metres. Exuding allelopathic compounds the plants smother and suppress all vegetation below.

During seeding, the plants are adorned with fluffy balls of barbed parachute-like seeds that float from the plant with the slightest knock or puff of wind. Across Asia, Africa and the Pacific islands, the weed is renowned for out-competing horticulture, native vegetation and reducing available pasture. It is an allergen to many humans and toxic to livestock-leading to aborted calves and, in extreme cases, death (Parsons & Cuthbertson, 2001).

During a trip to Timor and witnessing the vast understory of chromolaena throughout the landscape, Wilson (1994) could not help but note the similarities in the climate and eucalypt savannah vegetation with the Top End. His report warns of chromolaena as "*the premier weed threat to Northern Australia*" and provides a depressing vision that unless action is taken to prevent chromolaena establishing he could see a Top End covered in mimosa, chromolaena and rubber vine.

The close proximity of major chromolaena infestations across Asia, and now sadly northern Queensland (QLD), meant the likelihood of it finding its way to the NT was feasible, and somewhat expected. Not so much a matter of if, but how, when and where?

Historically, major efforts have been undertaken to prevent chromolaena spreading to our shores. It was considered such a threat that following the INTERFET campaign in Timor Leste, Australian Quarantine staff were posted overseas to inspect the wash-down of returning military equipment. The effort was of a massive scale. Reportedly up to 300 Defence personnel operated 20 wash stations, 18 hours a day for three months (Waterhouse & Zeimer, 2000).

Though the NT is remote place, the pathways for weed spread generally remain the same as elsewhere. New incursions tend to be associated with deliberate plantings or follow movement of livestock, machinery, vehicles or soils. Following this logic, generally, they appear in gardens or places associated with disturbance. Roadsides, culverts, industrial areas, cattle yards, creek crossings, clearings or cropping paddocks.

So, in July 2019 it was not so much a surprise that chromolaena was detected in the NT, but where it was detected. On a remote cattle station to the west of Darwin, hidden amongst the unproductive and densely timbered uplands of the Reynolds River floodplains.

Ground zero, as it is referred to, finds the chromolaena positioned amongst rocky outcrops, supporting stands of large old growth banyan figs, bombax and milkwoods. Chromolaena was also found along seasonal springs and drainage lines that feed melaleuca swamps and the vast seasonally inundated floodplains.

Whilst the origin of the infestations discovered in QLD in 1994 are recognised as contaminated pasture seed imported from Brazil in the 1960's (Scott, 1996), how it found its way to the NT remains a mystery. What is known, similar to the timeline in QLD, is that chromolaena is believed to have been present in the NT for ~10-20 years prior to its discovery (McKenna, 2019).

OUT OF SIGHT, OUT OF MIND

Mimosa pigra (mimosa) has long been a scourge on the floodplains of the NT. Infestations severely reduce carrying capacity, hinder stock movement and reduce available pasture (NTG, DoR, 2013). The floodplains of the Top End are highly prized for finishing cattle ready for market. As such, the properties surrounding ground zero spend many hundreds of thousands of dollars annually on mimosa control. Doing so sees a direct financial return for effort, as well managed floodplain grazing is very profitable enterprise, with the resultant live-weight gains of 0.5kg to 1kg per day during the dry season to early wet (NTG, DoR, 2013).

Conversely, the surrounding uplands areas do not support nutritious fodder. They cannot maintain large numbers of cattle held over the wet season and are easily subject to overgrazing. Uplands are considered of lower economic importance, producing little, if no, financial return (NTG, DoR, 2013). As such, the bushland areas are relatively disregarded and seldom visited. Often, the only real management being asset protection burns to firebreak the floodplains, or back burning to counteract coming wildfire. It is easy country for a weed to remain out of sight and out of mind.

DELINEATION IS KEY TO ERADICATION

The discovery in 2019 elicited an emergency response led by the Weed Management Branch of the Northern Territory Government Department of Environment, Parks and Water Security (DEPWS).

In an emergency response the initial goal is almost always eradication. After all, to find a weed you had been cautioned about all your career and not try to kill at all costs is a very hard urge to quash. The feeling is to go hard and go fast, with a kill 'em all attitude - prevent seeding at all costs and begin the countdown to eradication.

An Incident Management Team (IMT) was set up and liaised widely with the pastoral industry, primary industries, Aboriginal groups, Parks and other land managers. Emergency funding for immediate survey, treatment, communications and extension was secured. Importantly the IMT sourced knowledge about the habits of the weed and the issues learnt in running a chromolaena eradication program. Much information, good and bad, was garnered from researchers and land management officers involved in the ultimately unsuccessful QLD Siam weed eradication program (QSWEP). The key messages being to look far and wide and don't concentrate all your resources in one area as the weed may be hiding on the other side of the hills.

Barring two small roadside outliers, over the first two years of survey all chromolaena found sat within a diameter of 10km from 'ground zero.' All known plants remained on the original pastoral property and the neighboring Aboriginal Land Trust. Eradication, though considered ambitious, remained feasible in the minds of officers involved.

One of the main lessons learned through QSWEP is that constant delineation is the key to eradication (Jeffery, 2012). Though thought to be contained in a relatively small area, like the QSWEP experience, the population of chromolaena in the NT had a long head start.

There was a consensus for the need to conduct significant surveillance from the air. However, the rationale, cost and scale was open to conjecture and debate. Whilst one approach is to focus intensively around the known infestations and radiate out as new finds are revealed, the other theory is to look as far and wide as possible. A problem then arises how far, how wide and where?

The COVID pandemic meant that across DEPWS little remote fieldwork was able to take place. This left a surplus across operational budgets and as a result funding became available for a once-off aerial survey.

The IMT had maintained the idea of eradication. As such, the announcement to industry partners of large-scale aerial survey over country with no

connection to the known chromolaena infestations caught the ire of several, with one prominent industry member stating '*taxpayer money should be used for weed control - not scenic flights'*.

Though survey is critical to any eradication program it can be seen as an easy option – wasting money whilst avoiding laborious control work. Funding for large scale aerial surveillance is not cheap and is often hard to come by. At ~$1000-$1500 per hour for helicopter hire alone, the cost of aerial survey often far outweighs expenditure on seasonal control.

Concerns aside, the final consensus was to look as far and wide as possible. The approach taking a big risk that nothing would be found. The method of survey utilised a grid approach around the known infestations, and then followed a more fluid route, targeting likely habitats and paths of spread across the remainder of the survey. The experience with chromolaena to that point had indicated a preference for rocky outcrops, riparian edges and other habitats where it could establish protected from fire in its initial year.

Coinciding with peak flower in July 2021, survey took place over four weeks covering ~9,500km^2 of the western Top End. It crossed five major river catchments and covered numerous pastoral properties, Aboriginal Land Trusts, National Parks, Defence land and many private properties.

The results changed the narrative of chromolaena management in the NT. Chromolaena is now known to be present on 10 properties with the farthest 120km from ground zero. Large range extensions were found on the two known infected premises and another 'core' infestation was discovered on a separate cattle station approximately 40km from ground zero.

Chromolaena proved itself to be less selective than initially thought. It was found across many differing land types; Open savannah woodland, pandanus grasslands, coastal scrublands, paperbark swamps and floodplain margins. Persisting in areas of thick clean pasture and holding its own amongst other formidable weeds, notably mimosa and bellyache bush (*Jatropha gossypiifolia)*. In fact the only habitat it was not found on was the seasonally inundated floodplains.

The locations of new infestations surprised all experts involved in the program, many occurring in areas unrelated to other known populations. Having no connection to infrastructure, downstream movement of water or animal tracks. The only logical method of long-distance dispersal over the landscape being attributed to wind.

DISPERSAL BY DUST DEVIL?

Chromolaena produces massive quantities of seed with records of up to 86,000 seeds per plant (Gautier, 1993). Being apomictic - having no need for seed fertilization, one plant is all that is required to begin an infestation.

Each seed is adapted for spread by various means. A fine pappus, which enables the seeds to drift in the wind; rows of fine barbed hairs along the stem which stick to clothing, fur and machinery; and the ability to float, or be immersed in fresh, or saline water, for extended periods of time without degrading viability (Brooks, 2017), ensures once a plant seeds it has many avenues to spread and proliferate.

Wind is accepted as the main vector for short distance spread, but it had been considered unlikely to disperse seed more than 100m from the parent plant without significant updraft. Rather, long distance dispersal being generally attributed to water, or hitchhiking on animals, humans and vehicles (Brooks, 2017).

Seeding occurs August - October, coinciding with the climax of the Top End dry season and the more unstable weather of the build-up. The time of year is synonymous with hot blustery winds and large dust devils or willy-willys. These are vortexes of hot wind which roll across the landscape picking up soil, ash, leaves and debris propelling them into the air.

Dust devils range from small fleeting swirls in the grass to huge, long-lasting columns of debris visible across the horizon. It was during ground surveys in 2021 a seeding Chromolaena bush was observed being run down and buffeted by a dust devil.

Seed rain across Greater St Lucia Wetland Park in South Africa has been previously hypothesized, and somewhat debunked by Blackmore (1998) However; the spread across the NT suggests there are few other methods that could enable such a random distribution across lands disconnected by movement of animals, vehicles or flow of water.

It is a hard to prove, yet a plausible theory, that seed could be picked up from the plants and dragged up high into the air where it is at the mercy of the prevailing winds.

Providing more weight to the theory, the Finniss-Reynold's floodplains are well known for predictable south easterly dry winds during much of the day, with a westerly sea breeze in the afternoon. If the dust

devils can lift the seed high enough, there is no reason preventing seed dispersal many kilometres in multiple directions. If the theory proves correct, it has to be accepted that some methods of spread are unavoidable.

REALITY BRINGS NEW FOCUS

The sporadic nature of chromolaena distribution over the landscape and the distances between known infestations suggest there is more chromolaena that remains unaccounted for. To paraphrase Donald Rumsfeld's analogy 'there are unknown knowns'. The reality being that eradication in the NT is no longer feasible.

Efforts of the NT Chromolaena program are now transitioning from an in-house eradication program to land holder extension and research into techniques and controls most applicable to the Northern Australian savanna with a view to early intervention, containment and mitigation of further spread.

Working with Biosecurity QLD, building on their research conducted during and following QSWEP, the chromolaena program in the NT has shifted focus to giving land managers a variety of best practice tools to manage the weed, if and when, the need should arise

Paramount to this is to provide cost effective options for treatment, be that ground, foliar, soil applied or aerial solutions for treatment through different times of the year.

Poor roads, rugged terrain, seasonal flooding and the presence of a healthy population of crocodiles, (seemingly in every available body of water), mean access to many of the chromolaena infestations on ground is limited for much of December through to July. This means conducting ground control using conventional foliar spraying, splatter guns or hand removal is often impractical and unable to be conducted by land holders over a large area. As such there is major emphasis placed on developing a cost-effective methodology for aerial control using conventional equipment.

FIRE INTEGRATION

Fire's prevalence in the landscape necessitates any research into control methods integrate the timing of traditional burning practices. Traditionally fire is used to 'open up' the country, promote a new flush of growth, and protect assets and susceptible country from late season wildfires.

Chromolaena is a fire tolerant species once the root ball has established. However, well managed fire in the lead up to or during flowering has been shown to be a very handy tool for preventing plants from setting seed. Fire also allows better access and follow up control on the new flush of growth.

Conversely, burning the plants too soon after chemical treatment has shown to nullify the effects of the chemical control. As such, the program is working on techniques to allow longer intervals between control and fire to ensure the best results.

REMOTE SENSING

Remote sensing is being explored in partnership with Charles Darwin University. Investigation thus far has looked into hyperspectral bandwidth analysis, spectral reflectance curve, map based, pixel based and single image object based machine learning.

The most effective method thus far is using single image object-based machine learning, utilising geolocated, UAV captured hi-res RGB imagery. The machine learning model demonstrated a very high rate of success in identifying flowering chromolaena amongst background vegetation.

NT-based field trials will take place in July 2022. If successful, it is hoped to upscale the carrier aircraft from UAV to helicopter and ultimately a light aircraft. The latter being much faster and able to economically cover large areas of terrain while the plant is in flower.

As the machine learning system is almost fully automated it does not require spotters… less time for scenic flights and more time for control!

THE NT NEEDS MORE FLIES

Fortuitously, QLD Department of Agriculture and Fisheries Biosecurity completed Australian host specificity testing and risk analysis releasing the chromolaena biocontrol agent *Cecidochares connexa* just prior to the NT chromolaena incursion being discovered.

Through support from Biosecurity QLD, the NT has been rearing and establishing colonies on the 'core 'infestations since receiving the first flies in 2019.

The flies lay eggs in the growth tips of the plant. The galls form on the stems as the plant grows reducing vigor and seeding potential. A core component of the project moving forward is increasing the production and ramping up releases onto larger infestations to aid in seeding suppression. The flies are currently established at two separate locations, with new galls appearing on plants up to 300m from the release sites.

ALL IS NOT LOST

Acceptance of moving from eradication to management has been hard to take. Though it also needs to be acknowledged that continuing down a fruitless path can be demoralising and demanding on those involved. Accepting the change and working to develop awareness, tools and the best practice required to tackle chromolaena will hopefully provide better outcomes for NT land managers and the wider northern Australia into the future.

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