RHODES UNIVERSITY
Where leaders learn

CBC

Centre for Biological Control

Annual Report 2024

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Front cover photograph
Liam Yell, Karla Jaschke and Jackey Mukhawana at an ice plant site in the Northern Cape.
Photo: Emma Sandenbergh

Back cover photograph
Grant Martin, Nthambeleni Bologo and Sandy Steenhuisen doing post-release evaluations.
Photo: Obed Mugane

Editor
Kim Weaver

Design and layout
Bronwyn Tweedie
Print Services Unit, Rhodes University

Contents

DIRECTOR'S REPORT

2024 was yet another busy year for the CBC with many projects continuing and a number of new projects being started. Each year that I go through the draft report I am amazed not only by the diversity of projects that are being undertaken by our researchers and students, but also the quality of the research which is borne out in the high-quality publications and international conference presentations that are produced annually. This last year also saw us graduate a good number of postgraduate students, all of whom are making a significant contribution to the broad discipline of biological control. I would like to thank the supervising teams for ensuring that our students produce high-quality theses that meet internationally accepted examination criteria.

It was a very busy year on the conference front with the CBC organising and hosting the annual National Symposium on Biological Invasions in collaboration with the Centre for Global Change, Faculty of Natural and Applied Sciences, and the Department of Biological and Agricultural Sciences, Sol Plaatje University, and the South African Environmental Observation Network, Arid Lands Node. This meeting brought together some 125 delegates from all over the country to discuss recent research into biological invasion. A highlight of the meeting was that it was attended by 12 delegates from the National Centre for Vegetation Cover Development and Combating Desertification, and Tilad, Kingdom of Saudi Arabia who were attending a two-week long Summer School on biological control hosted by the CBC.

We also had eight delegates attend the International Congress on Biological Control (ICBC3) in Costa Rica in June where, in my position as president of IOBC Global, I was part of the organising committee. The importance of this meeting is that it brings together the two broad sections of biological control (weed and insect pest). Iain Paterson attended the International Congress on Entomology held in Kyoto, Japan, in August, where he presented South Africa's bid to host the 28th International Congress of Entomology on behalf of the Entomological Society of Southern Africa. The bid was successful, and we now have our work cut out over the next few years to ensure that it is a good meeting.

Other noteworthy research achievements on the weed front in 2024 include:

- the importation of a new lineage of *Dactylopius tomentosus* for thistle cholla, *Cylindropuntia pallida*;
- the importation of *Anthonomus morticinus* for *Solanum mauritianum* at Wits University;
- the establishment of *Listronotus appendiculatus* on *Sagittaria platyphylla*;
- the establishment of a bud-galling wasp, *Perilampella hecataeus* on *Acacia baileyana* and *A. dealbata*;
- the complete control of *Pistia stratiotes* by *Neohydronomus affinis* on the Vaal River Barrage, only to be replaced with water hyacinth;
- highly successful control of *Salvinia molesta* by *Cyrtobagous salviniae* in Zimbabwe;
- a number of insects new to science being collected off indigenous grass species that are invasive elsewhere in the world.

The agricultural entomologists have also been really busy with several trials, forcing us to rethink the value of augmentative releases of imported parasitoids, and some new research that will improve the success of the SIT programme against false codling moth. We have also initiated some research in collaboration with CRI on the role of psyllids in citrus orchards to prepare the industry for the possible introduction of the psyllid *Diphorina citri* that vectors Asian Greening disease.

There was also some movement of staff during 2024 with Julie Coetzee taking up a prestigious SARChI chair at NRF – South African Institute for Aquatic Biodiversity. This is a chair jointly held between SAIAB and Rhodes University and will not only expand the scope of the research that Julie does on aquatic invasions, but also provide more collaboration and capacity to the CBC. During the year Iain Paterson was promoted to Full Professor, Grant Martin to Associate Professor, and Guy Sutton to Senior Researcher. Well done to Nic Venter for securing a permanent position as Senior Lecturer at Wits University.

Having attended a number of conferences during 2024, I am concerned about the proliferation of specialist conferences that result in biocontrol practitioners presenting research to fellow biocontrol practitioners. There is a place for these conferences, but I also believe that there should be an obligation for us to present our research to a broader community of scientists, including the ecological and conservation lobby who have been critical of biological control in the past. We do some outstanding, high-quality science that has far-reaching implications, and we should not shy away from presenting this to a critical audience. In doing so, we will ensure a wider uptake of biological control. This also applies to the journals we publish in.

I thank all of the staff and students of the CBC, our collaborators and funders for the support during 2024. In particular, I would like to thank Kim Weaver for pulling together yet another outstanding annual report.

The CBC Team

STAFF

Director
Prof. Martin Hill

Deputy Directors
Prof. Julie Coetzee
Prof. Grant Martin
Prof. Sean Moore
Dr Samuel Motitsoe
Ms Samella Ngxande-Koza
Prof. Iain Paterson

Research staff
Dr Candice Coombes
Philip Ivey
Dr Michael Jukes
David Kinsler
Wandisile Mdiza
Ntando Mkhwanazi
Phillippa Muskett
Emma Sandenbergh
Dr Guy Sutton
Jaqui van Dyk
Kim Weaver

Centre administrators
Jeanne van der Merwe
Ticia Swanepoel

Mass-rearing facility staff
Waainek, Makhanda
Samella Ngxande-Koza (Manager)
Landile Booi
Nokuthula Kom
Mthobeli Mvandaba
Siyaxolisa Mini
Nandipha Ngolothi
Siyanda Ntamo
Vuyani Ntyinkala
Lyle Titus

Kariega
Ruth Scholtz (Manager)
Karin Goliath
Lubabalo Malinga
Gugulethu Mkile
Carmen Peters
Ronel Roman
Arthur Scholtz
Daniel Scholtz
Byron Soetland

Postdoctoral Fellows
Dr Nompumelelo Baso
Dr Kim Canavan
Dr Lenin Chari
Dr Gerald Chikowore
Dr Daniella Egli
Dr Kelby English
Dr Tamzin Griffith
Dr Tapiwa Mushore
Dr Marcel van der Merwe
Dr Clarke van Steenderen

STUDENTS

Doctoral students
Tahnee Bennett
Tafara Frank Bute
Luke Cousins
Ernst de Beer
Wayne Kirkman
Shaun Manzini
Michael Mathenge
Siya Mnciva
Karlien Muller
Keneilwe Sebola
Vhuawelo Simba
Deric Vershiyi Tanka
Siviwe Tole
Garyn Townsend
Liam Yell

Masters students
Rochelle Bessinger
Nthambeleni Bolongo (UFS)
Erin Boon
Tressia Chikodza
Ben de la Fontaine
Kundai Dube (UFS)
Danie Grabe
Tadiwa Kambani
Kurhula Luphondo
Lesego Malekana (UFS)
Lulutho Mancunga
Soso Maneli
Thoriso Masalesa
Tapiwa Mashamba (UFS)
Patricia Masole (UFS)
Thembelihle Mbele (UFS)
Raynold Moagi
Wayne Mommsen
Sifundo Ngxekisa
Siyabonga Phoswa
Zinhle Sithole (UFS)
Emma Stirk
Wade Sexton

ASSOCIATES

CBC Consortium partners
University of Witwatersrand
Prof. Marcus Byrne
Dr Nic Venter

University of Cape Town
Associate Prof. John Hoffmann
Fiona Impson
Catharina Kleinjan

University of Free State
Prof. Sandy Steenhuisen

University of Mpumalanga
Ludzula Mukwevho

University of Fort hare
Dr Unathi Heshula

Research Associates
Prof. Caroline Knox (RU)
Prof. Terry Olckers (UKZN)
Dr Reyard Mutamiswa (RU)
Dr Costas Zachariades (ARC-PHP)

AQUATIC WEEDS

At the beginning of 2024, Julie Coetzee took up a new position as Principal Scientist at the NRF South African Institute for Aquatic Biodiversity (NRF-SAIAB). Julie was awarded a South African Research Chair (SARChI) by the NRF, which is held jointly by Rhodes University and NRF-SAIAB. Her Chair is focused on the ecology and management of aquatic invasive species, with an emphasis on biological control of aquatic invasive plants. Julie remains a Deputy Director of the CBC, and manages the aquatic weeds programme

The CBC's research into, and implementation of biological control against aquatic weeds in South Africa continues to contribute to the fight against aquatic weeds that degrade our aquatic ecosystems, with knock-on socio-economic impacts. The team's research was brought into the spotlight when an extensive section of the Vaal River Barrage was invaded by water lettuce (*Pistia stratiotes*), and later *Pontederia crassipes* (water hyacinth). Together with Rand Water and local stakeholders, the CBC implemented an integrated management plan for both of these notorious waterweeds, including a strong focus on biological control. This programme received a lot of publicity, and highlighted the importance of biological control for aquatic weeds. Towards the end of the year, Rand Water appointed the CBC as their biocontrol implementing agent, and this has allowed us a strong collaborative working relationship with the entity.

We continue to support mass rearing and release efforts at Hartbeespoort Dam, where *Megamelus scutellaris* once again reduced the water hyacinth cover to below 5% at the end of summer in March 2024. The CBC also plays a strong role in promoting biocontrol of waterweeds through our collaborations with water managers across the country. Our Waainek Mass Rearing station has once again released thousands of biocontrol agents across South Africa, and we have sent a consignment to the USA to improve their prospects for water hyacinth control.

The submerged and emergent weed research is progressing very well. This year we confirmed establishment, after winter, of *Listronotus appendiculatus*, which was released against *Sagittaria platyphylla*, in October 2023. We received permission to release the Florida biotype of *Cyrtobagous salviniae* for control of *Salvinia minima*, whose range has extended along the Crocodile River Catchment and into the Limpopo River. The *Iris pseudacorus* biocontrol programme has not progressed very far in the last year, largely due to funding constraints, but we hope to finalise multi-generation tests of the potential agent, *Aphthona nonstriata,* on *Iris* cultivars important to the Nursery Industry to ensure we understand any potential impacts to these cultivars. We continue to monitor systems in southern Africa for new invasive macrophytes, and have completed a study on the distribution of Amazon frogbit (*Hydrocharis laevigata*) in Zimbabwe.

PROGRAMME HIGHLIGHTS IN 2024

- Julie Coetzee was awarded a SARChI for the next five years, based at NRF-SAIAB.
- Establishment of *Listronotus appendiculatus,* released against *Sagittaria platyphylla,* confirmed in Makhanda and Pietermaritzburg.
- Ten community rearing stations are in operation at Hartbeespoort Dam, and three on the Vaal River Barrage.
- Rearing stations released ~550 000 *Megamelus scutellaris* between August and December 2024.

Restoration research is underway, and adds an important component to biological control programmes that should be conducted as a matter of course. A multi-national research programme on the interactions between invasive aquatic plants and invasive mosquitoes, across continents, called MOZiMACs, was established, and will contribute to the global One Health research programme.

Water hyacinth

The augmentative biological control programme against water hyacinth continued in 2024. This management strategy involves the regular release of *Megamelus scutellaris* on water hyacinth, which is reared at the CBC's Waainek Research Facility and a network of new and established satellite rearing stations managed by local community members. This approach has proven effective in previous years, particularly when introduced at the right time, such as in the Highveld region, where cold winters occur. The focus has been on springtime agent introductions when water hyacinth experiences rapid growth following winter dormancy. In addition to mass-rearing and release efforts, several research projects investigate various aspects of water hyacinth and its biological control agents. These include post-release evaluations, the effects of sub-lethal herbicide doses on agent populations, the impact of biological control on the decomposition rate of water hyacinth, and the effects of acid mine drainage on agent survival and persistence.

RESEARCH TEAM
Prof. Julie Coetzee, Prof. Martin Hill, Dr Samuel Motitsoe, Dr Antonella Petruzella, Dr Kelby English, Dr Daniella Egli, Dr Guy Sutton, Dr Gerald Chikowore, Dr Trishan Naidoo, Prof. Ryan Wasserman and David Kinsler.

STUDENTS
Siyasanga Mnciva (PhD), Tafara Frank Bute (PhD), Liam Yell (PhD), Rochelle Bessinger (MSc), Riaan Labuschagne (MSc), Keneilwe Sebola (PhD), Stefanie Botha (MSc), Jane Doherty (PhD).

COLLABORATORS
FuEDEI, University of Corrientes, Vrije Universiteit Brussels, Manaaki Whenua-Landcare Research, Louisiana State University, USDA-ARS Invasive Plant Research Laboratory, MadMacs, Stellenbosch University.

Hartbeespoort Dam

Chemical control using herbicides was ceased at the end of 2016. In 2017 water hyacinth increased steadily under ideal conditions of summer and through the cold winter months. Cover reached a peak of ±40% in the spring after which it began to decline, due to suspected recovery of biological control agents released in the 1990s. Over the next two years water hyacinth cover was not impacted by cold temperatures.

In 2019, the CBC began inundative releases of *Megamelus scutellaris* and by the end of February 2020, the water hyacinth mat collapsed from ±30% to less than 10%, and further reduced to ±5% over the winter months. Due to the extensive seedbank lying dormant in the sediment, the plants resurged in spring (October 2020). The CBC continued with its inundative release campaign over the spring and summer and in January 2021, the mat collapsed once again. This pattern has repeated in the following years, including this last season in September 2024 when plants resurged again.

Water hyacinth is the only plant that its host specific biocontrol agents can feed and reproduce on, so when the mat collapses, the agent population follows shortly after. This necessitates the need to rear the agents for inundative releases to begin as soon as the plants resurge.

Each year, the seed bank is being depleted in spring when seeds germinate and plants resurge. The biocontrol agents are reducing the flower production of the plants thereby reducing the seeds being added to the seed bank. This indicates a multipronged success in controlling the water hyacinth invasion on Hartbeespoort Dam.

This data was analysed over a long period to confirm the collapsing water hyacinth mat is due to the biocontrol programme. The inundative releases and post-release evaluations will continue to be carried out by the CBC.

Does heavy metal pollution affect biological control success of water hyacinth?

Pollution from excess inorganic nutrients and metals has caused significant eutrophication of dams and rivers in the Highveld region. Water hyacinth is well known for its phytoremediation capabilities, as it can absorb chemical pollutants, including metals, and sequester them within its biomass. In South Africa, mining activities leave a lasting legacy of sulphide mine tailings, such as those found in the Blesbokspruit wetland, a Ramsar wetland located on the East Rand. The chemical breakdown of sulphide in the presence of oxygen and bacteria leads to the formation of acid mine drainage, which releases acid, metals, and sulphates into water systems, making

these substances biologically available. Additionally, sewage introduces heavy metals, such as lead, cadmium, and nickel, which contribute to the contamination of water reserves throughout the country.

While water hyacinth's ability to absorb these contaminants can help remediate water quality, it may also have unintended consequences for biological control efforts. The uptake of metals by the plant can expose biocontrol agents, such as *Megamelus scutellaris*, a phloem feeder, and *Neochetina* weevils, which are tissue feeders, to the accumulated contaminants through their feeding activity. However, there is limited research on how environmental pollutants affect the biology and physiology of herbivorous insects exposed to these substances, including biocontrol agents of water hyacinth. One area of concern is the potential for these pollutants to alter the insect-gut microbe communities.

To address this gap, PhD student, Frank Bute, is conducting research using a catchment approach around waterbodies in the East Rand region of Gauteng to examine the impact of metal toxicity on insect-gut symbiosis. Concentrations of 20 heavy metals from the water of seven waterbodies were measured using inductively coupled plasma-optical emission spectrometry. The results indicate alarming levels of metal pollution in the East Rand catchment, with 15 metals exceeding the *DWS water quality guidelines* (Figure 2). Notably, high salinisation levels from magnesium (Mg), calcium (Ca), and sodium (Na) were associated with elevated concentrations of AMD-related metals such as iron (Fe), Manganese (Mn), and Aluminium (Al). Metals are systemic toxicants that can induce multiple organ damage, even at lower levels of exposure.

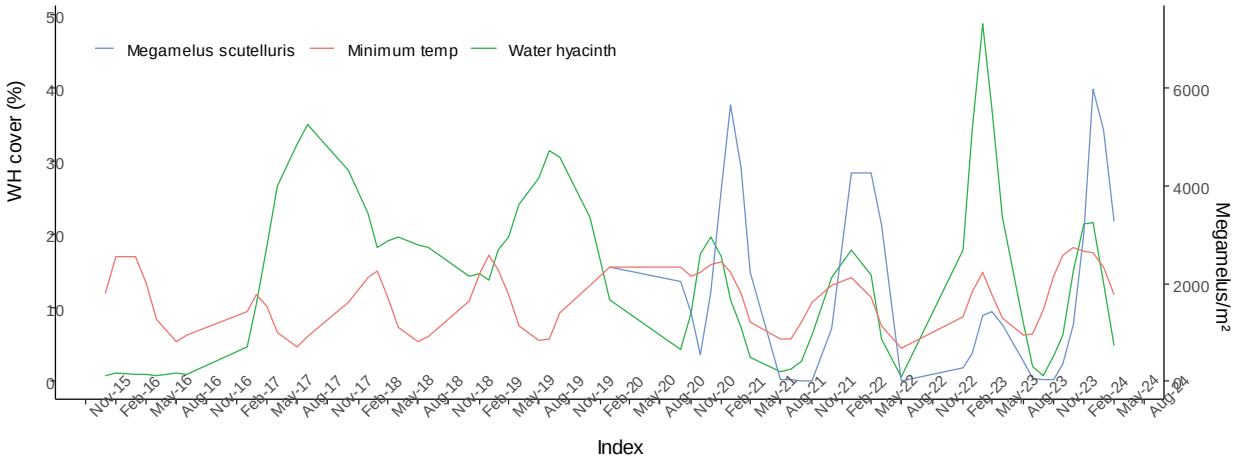

Figure 1. Temporal dynamics of *Megamelus scutellaris* density (blue line, individuals/m²), minimum temperature (red line, °C), and water hyacinth *(Eichhornia crassipes)* cover (green line, %) from December 2015 to August 2024. The x-axis represents the time series, while the left y-axis indicates the percentage cover of water hyacinth, and the right y-axis corresponds to *Megamelus scutellaris* density.

Inorganic Constituent	Unmodified, natural A	Largely Natural B	Moderately impacted C	Largely impacted D	Seriously impacted E	Critically impacted F	Witfield Dam	Middle Lake	Civic Dam	Jan Smuts Dam	Presidents Dam	Blesbokspruit Wetland	Blesbokspruit Downstream
Sodium	<=4.100	<=8.600	<=13.546	<=21.884	<=51.084	> 97.300	16.000	20.333	21.667	53.000	55.333	65.333	110.333
Potassium	<=1.100	<=2.206	<=3.0300	<=4.1360	<=8.2000	> 15.500	5.367	4.500	32.333	29.000	13.933	11.333	10.833
Calcium	<=8.400	<=12.03	<=17.200	<=26.623	<=43.954	> 100.20	21.333	27.000	29.333	40.667	36.667	40.333	167.667
Magnesium	<=3.300	<=5.100	<=7.9620	<=12.800	<=21.244	> 33.044	9.667	11.333	13.000	20.333	15.667	15.333	54.667
Aluminium	<=0.005	<=0.026	<=0.035	<=0.091	<=0.229	> 0.912	0.052	0.104	0.038	0.145	0.134	0.930	1.315
Arsenic	<=0.001	<=0.001	<=0.001	<=0.001	<=0.001	> 0.002	0.001	0.001	0.001	0.001	0.016	0.003	0.028
Boron	<=0.004	<=0.006	<=0.006	<=0.011	<=0.021	> 0.067	0.000	0.000	0.000	0.152	0.064	0.056	0.164
Copper	<=0.002	<=0.006	<=0.006	<=0.006	<=0.010	> 0.022	0.011	0.012	0.000	0.011	0.011	0.010	0.012
Iron	<=0.003	<=0.019	<=0.143	<=0.403	<=0.800	> 2.220	0.972	0.304	1.373	0.612	1.255	2.731	3.739
Lead	<=0.001	<=0.004	<=0.036	<=0.036	<=0.054	> 0.063	0.004	0.000	0.001	0.003	0.001	0.010	0.012
Manganese	<=0.001	<=0.001	<=0.001	<=0.002	<=0.021	> 1.350	0.142	0.179	1.042	1.352	0.995	0.606	0.816
Mercury	<=0.010	<=0.010	<=0.010	<=0.010	<=0.010	> 0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.01
Nickel	<=0.002	<=0.004	<=0.005	<=0.008	<=0.012	> 0.026	0.000	0.000	0.000	0.000	0.033	0.020	0.117
Phosphorus	<=0.005	<=0.015	<=0.029	<=0.049	<=0.121	> 0.780	0.038	0.023	0.614	4.253	0.392	1.970	0.798
Zinc	<=0.001	<=0.002	<=0.004	<=0.004	<=0.008	> 0.070	0.018	0.000	0.000	0.023	0.012	0.046	0.037

Figure 2. Water Quality Assessment of invaded East Rand lakes using *South African Water Quality Guidelines* Volume 7: Aquatic Ecosystems; Odume et al. 2024.

While a total of six sites were found to be hypertrophic for inorganic nitrogen (Figure 3), all seven sites were phosphorus-hypertrophic (>0.25 mg/L). Wastewater treatment plants and raw sewage leaks remain the primary contributors to the current hypertrophic status of wetlands in the East Rand, with the Blesbokspruit wetland system being the most polluted site. Seven wastewater treatment plants with cumulative capacities of approximately 170 ML/day discharge into Blesbokspruit upstream of the wetland.

The bioconcentration factor (BCF) represents the ratio of metal concentration in plant tissues to that in water; if greater than one (>1), the plant is a hyperaccumulator. Water hyacinth BCF values were >1 for eight metals, including Al, Fe, and Mn, in the Blesbokspruit wetland system. These findings point to a critical water quality crisis in the East Rand, characterised by high salinisation, metal pollution, and eutrophication, which could potentially undermine the success of the biological control of water hyacinth in the East Rand.

Molecular work is ongoing to assess potential dysbiosis in *M. scutellaris* populations due to heavy metal toxicity, possibly affecting the insect's fitness and establishment.

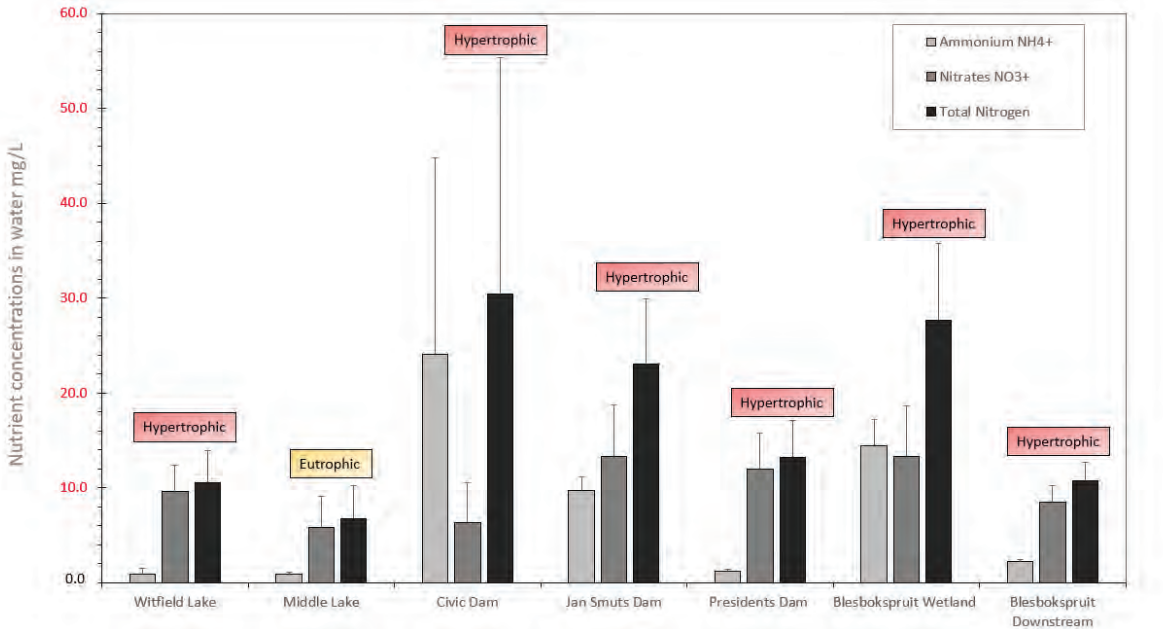

Figure 3. Bar graph showing the combined effects of ammonium (grey) and nitrates (dark grey) on total inorganic nitrogen concentrations (black) in the East Rand. Trophic status based on South African Water Quality Guidelines for inorganic nitrogen.

Figure 4. Molecular analysis for sequencing the gut microbiome of *Megamelus scutellaris*.

Detritus formation from decomposing water hyacinth

The decomposition of water hyacinth in aquatic ecosystems has been a topic of ongoing concern, particularly in regions like Hartbeespoort Dam. This invasive plant's rapid spread and subsequent decay can contribute to further eutrophication, exacerbating water quality issues in already nutrient-rich systems. Local stakeholders, including residents and environmental managers, have raised questions about the fate of the large volumes of plant debris produced as water hyacinth decays following biological control. Specifically, they are concerned about how the decomposing material might influence water quality and contribute to nutrient cycling in the dam.

Rochelle Bessinger, an MSc student, investigated the rate of detritus formation from decomposing water hyacinth plants. Rochelle performed mesocosm studies comparing

the rate of detritus formation between plants under biological control, with *Megamelus scutellaris,* herbicide-treated plants (Kilo Max), plants with no treatment (control) and a procedural control of no plants, at two time points. The interaction between treatment and time had a significant effect on detritus formation (X^2 = 66.50, df = 3, p < 0.001). The water hyacinth control and biocontrol treatments showed the largest increase in detritus across the two time points (1.17 g ± 0.20 and 1.36 g ± 0.24). The herbicide treatment was the only treatment to show a decrease in detritus from time point one to two (0.20 g ± 0.12). Additionally, the herbicide treatment had more than double the amount of detritus than any treatment at time point one. Still, by the end of time point two, the biocontrol and water hyacinth only treatments accumulated more detritus than the plant-free control but were not different from each other.

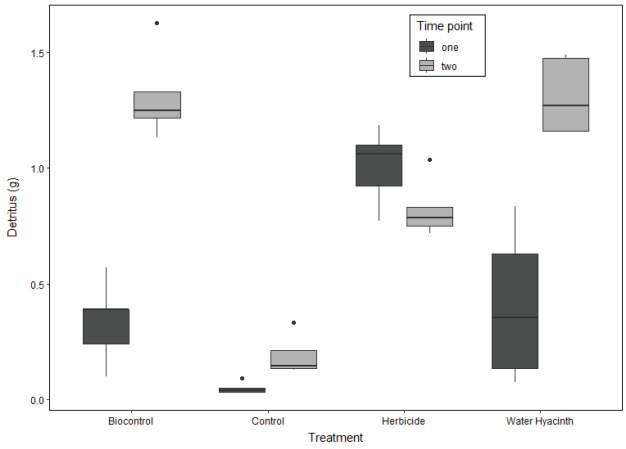

Figure 5. Detritus (g) measured across four treatments at two time points. Each treatment had five replicates (n=5) at each time point.

Field studies were conducted at Hartbeespoort Dam, where water hyacinth was placed inside wire cages in situ and were allowed to decay. Cages without water hyacinth were also placed within the same site, as plant-free controls. Each month (November 2023-April 2024), the amount of detritus was sampled. Significantly more detritus was collected in the water hyacinth present vs absent treatments (X2 = 41.56, df = 1, P < 0.005). The cages containing water hyacinth plants produced more than double the amount of detritus (386.09 g ± 0.12 g) than the cages without plants (157.35 g ± 0.12 g) (Figure 6).

Furthermore, a significant correlation was found between detritus formation and plant parameters. The strongest correlation was between detritus and the biomass of the roots (R = 0.64, P < 0.001) (Figure 7).

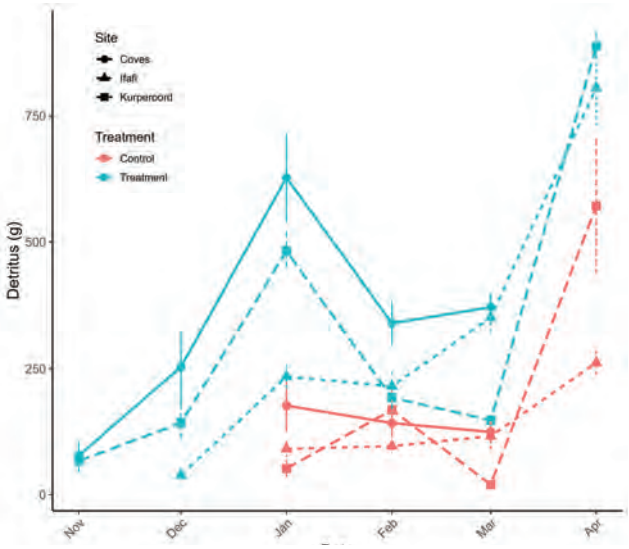

Figure 6. Detritus measured at each site on the dam – comparing cages with and without water hyacinth.

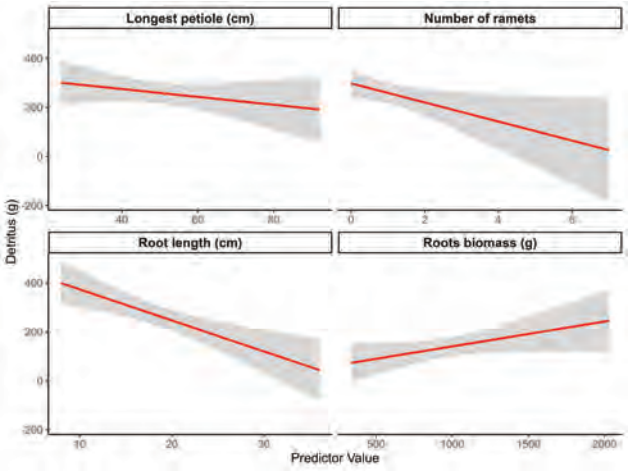

Figure 7. Trends between detritus formation and selected water hyacinth plant parameters.

The effect of plastic pollutants on water hyacinth biocontrol agents

Aquatic systems are degraded and negatively impacted by plastic pollution. However, the effects of plastic and its associated leachates on water hyacinth and its biological control agents are not known. The relationship between the health of the control agents and plastic leachates could be meaningful when attempting to improve the control of water hyacinth.

Riaan Labuschagne, an MSc candidate at the CBC, is investigating the effects of BPA and naphthalene on the survival of *M. scutellaris* and *N. bruchi* through experimentation mimicking field scenarios. His research aims to (1) investigate the time it takes for the plastic leachates to saturate the water hyacinth plants and how much this value is; (2) assess the survival of the two agents' species (adults) exposed to six different concentrations

of plastic leachates; (3) assess the development of the agents' nymphal life stage when exposed to six different concentrations of plastic leachates. The findings of this study will provide insights into whether organic chemicals associated with plastic pollution are another way that makes water hyacinth control difficult by affecting the associated control agents.

Post-release evaluations of *Eccritotarsus spp.*

Eccritotarsus catarinensis and *Eccritotarsus eichhorniae* are biological control agents released against water hyacinth in South Africa. *Eccritotarsus catarinensis* was released in 1996, and *E. eichhorniae* was released in 2007. Nationwide surveys between 2017 and 2019 showed that *E. catarinensis* was widely established in South Africa. However, *E. eichhorniae* was not found at any sites during these surveys, including its original release sites, despite numerous releases since 2007. Liam Yell, a PhD student, conducted further surveys between December 2023 and March 2024, during which *Eccritotarsus* spp. were found at six out of 45 sites. However, this result was influenced by a lack of hyacinth plants at several sites due to heavy rains and flooding in the months preceding the surveys. Genetic analyses are underway to determine which species of *Eccritotarsus* has persisted at each site.

Establishment data were used to assess whether climate may influence the distribution of *Eccritotarsus* spp. in South Africa. The presence/absence data from the 2023/2024 surveys were combined with the presence/absence data from the 2017/2019 surveys for climatic modelling (Figure 8).

Further surveys are planned to access sites that have not been surveyed thus far and to re-survey sites where no plants were present during initial surveys.

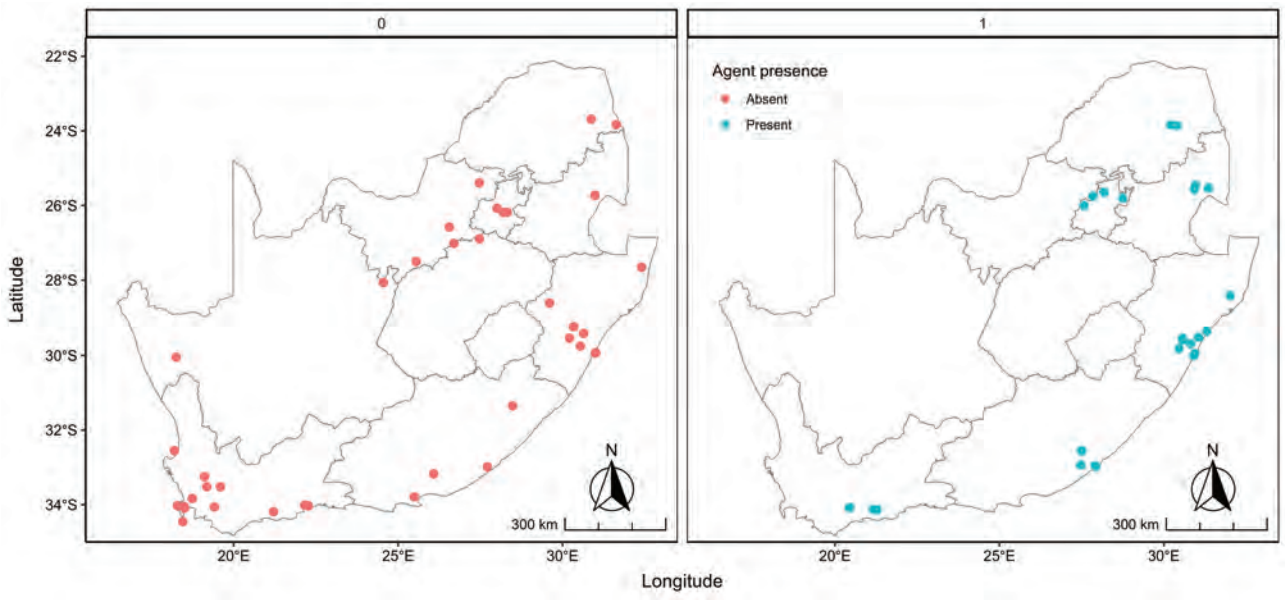

Figure 8. The presence and absence of *Eccrittotarsus* spp. across South Africa using the combined data from the 2017/2019 and 2023/2024 surveys.

Figure 9. Performing a survey to determine the establishment of *Eccritotarsus* spp. on water hyacinth in the Kruger National Park on the Letaba River in February 2024. Photo: Kelby English.

Integrated control of water hyacinth combining sub-lethal herbicide doses with biocontrol

Biological control agents of water hyacinth can significantly reduce the plant's invasive qualities by slowing down its vegetative growth and decreasing its seed production. However, biological control is often perceived to be too slow, particularly in eutrophic sites. Integrated water hyacinth control using careful applications of herbicides at sub-lethal doses and biological control agents may increase the rate of control. Siyasanga Mnciva, a PhD student, has explored and identified the impacts of combining a sub-lethal dose (0.4%) of a commonly used glyphosate-based herbicide, Kilo Max, and *Megamelus scutellaris* on water hyacinth control. Field studies were conducted at Bronkhorstspruit Dam, where combined control agent release and herbicide spray sites were established, paired with control sites where only insects were released but no herbicide sprayed. Water hyacinth growth parameters in the sprayed and control sites were sampled over a period of three months.

The results showed that the vegetative production of water hyacinth was reduced by the combination of sub-lethal herbicide dose and *M. scutellaris*. The number of leaves was significantly reduced in sprayed sites compared to unsprayed sites. Ramet production decreased in sprayed sites throughout the sampling period, but no significant differences existed in the unsprayed areas. The decrease in plant growth in sprayed areas was attributed to the sub-lethal herbicide application combined with herbivory by *M. scutellaris*. This suggests that sub-lethal herbicide-induced hindrance of vegetative growth resulted in substantial levels of damage by the biological control agents and further suppression of the weed through continued herbivory by *M. scutellaris*. These studies concluded that a sub-lethal dose of glyphosate-based herbicide is compatible with *M. scutellaris* insects, and the combined effect of these approaches is synergistic in controlling the invasiveness of water hyacinth.

Figure 10. Siyasanga Mnciva sampling *Megamelus scutellaris* in the field, October 2022. Photo: Tressia Chikodza.

Water weed invasions on the Vaal River Barrage: integrated management of water hyacinth and water lettuce.

Late in 2023, the CBC was alerted to a water lettuce (*Pistia stratiotes*) and water hyacinth invasion on the Vaal River Barrage, below the Vaal Dam. These invasive macrophytes spread upstream from the Vaal River Barrage, covering approximately 40 kilometres of the waterway by February 2024. Rand Water was appointed by the Department of Water and Sanitation (DWS) as the implementing agent, to manage the invasion, and the CBC was approached to contribute to the biological

control aspect of the management programme. Through an integrated management plan, local stakeholders, Rand Water, and the CBC have combined mechanical, manual, chemical and biological control to reduce the extent of the invasion. The first releases of the biocontrol agent, *Neohydronomus affinis*, were made in November 2023, followed by intensive inundative releases over the summer of 2024.

David Kinsler developed a macrophyte monitoring tool for the Vaal River Barrage section, which has allowed us to monitor the changes in water weed cover over time.

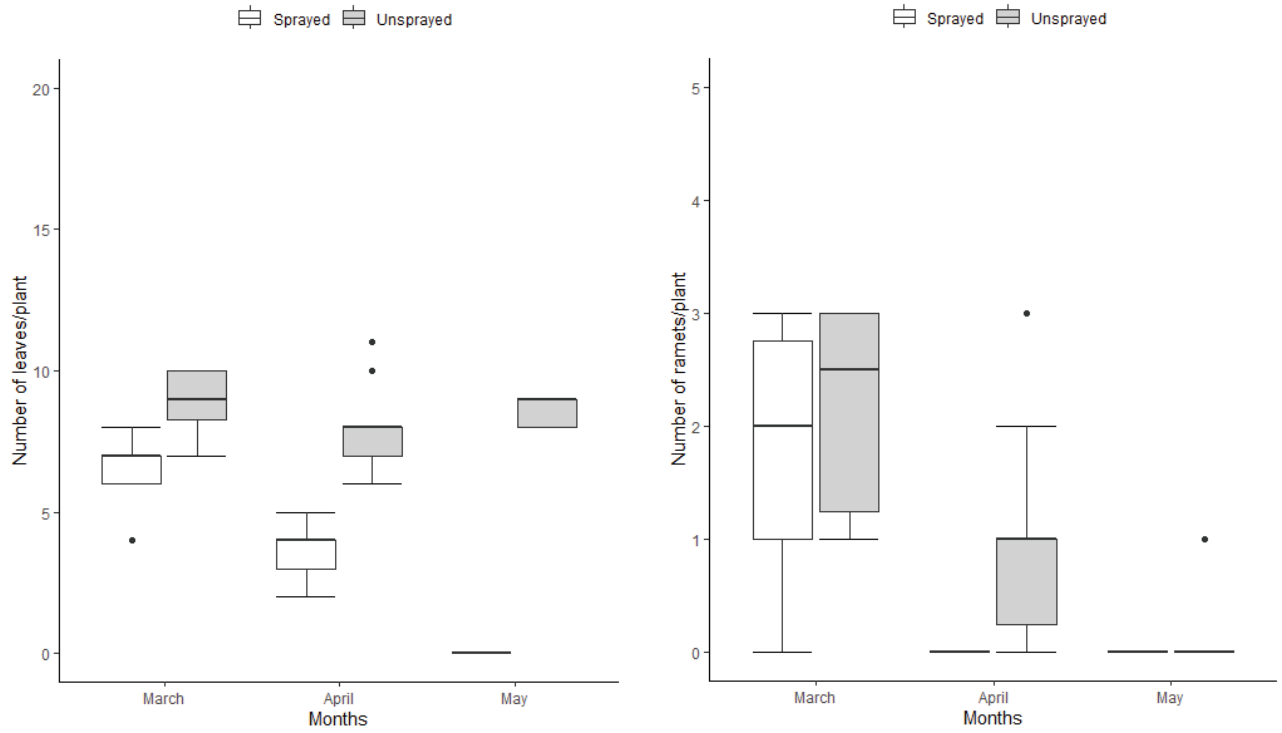

Figure 11. Number of leaves (left) and number of ramets (right) of water hyacinth in plots that were either sprayed with sub-lethal herbicide or unsprayed at Bronkhorstspruit Dam, Gauteng.

Figure 12. Water lettuce (*Pistia stratiotes*) on the Vaal River, March 2024.

Figure 13. Dr Kelby English releasing the water lettuce weevil, *Neohydronomus affinis*, onto the Taaibosspruit, a tributary of the Vaal River. Photos: Julie Coetzee.

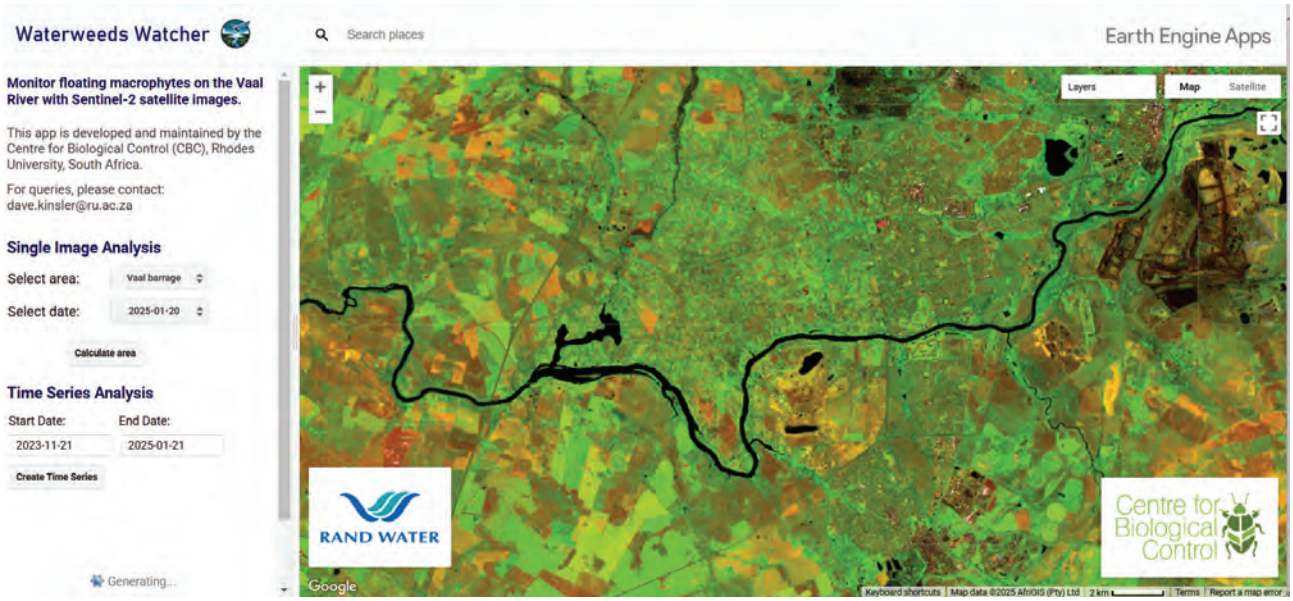

Figure 14. The Vaal River Waterweeds Watcher tool, developed by David Kinsler. https://centreforbiologicalcontrol.projects.earthengine.app/view/vaal-river.

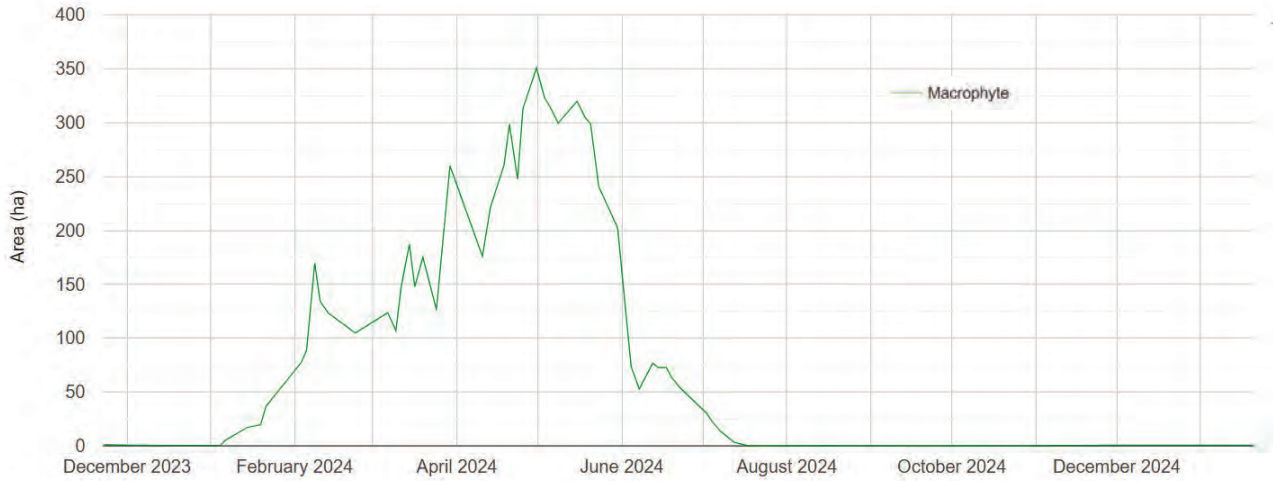

Figure 15. Water lettuce cover on the Vaal Barrage from December 2023 to December 2024. Cover reached a peak in May 2024, of ~350 Ha, and then decreased over the winter months due to a combination of control methods, and cold winter temperatures.

Post-release evaluation of the Vaal River Barrage

Madie Mbayela, an MSc student based at Wits University, joined the waterweeds team in May 2024. Her research focuses on the autecology of invasive aquatic plants in the Vaal River Barrage, particularly in areas affected by recent invasions of water hyacinth and water lettuce. The primary aim of Madie's research is to monitor and understand the dynamics of biocontrol agents introduced to manage water hyacinth and water lettuce, assessing their impacts on ecosystem processes within the river. Starting in June 2024, she has conducted monthly post-release evaluations of biocontrol effectiveness at eight designated sites, planned to carry on for a year. These surveys aim to gather data on both the population dynamics of the invasive plants, and the ecological changes following the biocontrol agents' release.

In addition to monitoring plant and agent interactions, Madie is collecting soil samples seasonally to analyse the seedbanks of both weeds. This analysis will help quantify the impact of biocontrol agents on the reproductive capacity of water hyacinth and water lettuce. Her research objectives also include the following specific aims:

1. to investigate the competitive relationship and population dynamics between water lettuce and water hyacinth in the invaded areas;
2. to evaluate the contributions of biocontrol efforts on water quality and broader ecosystem processes in the Vaal River Barrage;
3. to determine the damage efficiency per square metre for each specific biocontrol agent used against the invasive plant populations.

Figure 16. Madie Mbayela collecting soil samples at Suikerbossrand River. Photo: Sam Motitsoe.

Giant Salvinia

Salvinia molesta (giant salvinia) has, in recent years, become a problem aquatic invader on the Mokolo River. This is of international concern as this river leads into the Limpopo River which marks the border between South Africa and two southern African countries, namely Botswana and Namibia, eventually flowing through Mozambique to the coast.

RESEARCH TEAM
Prof. Julie Coetzee, David Kinsler, Dr Samuel Motitsoe, Dr Antonella Petruzzella and Samella Ngxande-Koza

COLLABORATORS
Louisiana State University, the African Marine Mammal Conservation Organisation (AMMCO)

The Centre for Biological Control (CBC) - Rhodes University first met with concerned stakeholders residing along the Mokolo River in January 2023. The team released a population of *Cyrtobagous salviniae*, the biological control agent for giant salvinia. Releases were made at the highest invasion point, which is the confluence of the Rietspruit at Molalatau Lodge, and several locations downstream. Since the first visit, several agent consignments have been sent to stakeholders for release. Approximately 400 weevils were sent in April 2023, 500 were released by the CBC team in June, and 200 in August 2023, and 1000 each were sent in April, July and October 2024.

Figure 17. Giant salvinia survey sites along the Mokolo River, Limpopo Province.

Figure 18. David Kinsler sampling giant salvinia on the Mokolo River, June 2024. Photo: Julie Coetzee.

Surveys

In June 2024, members of the CBC, the South African Institute for Aquatic Biodiversity, the Department of Forest, Fisheries and Environment, and the Department of Water and Sanitation conducted surveys along the Mokolo River to assess the giant salvinia invasion and the post-release establishment status of the biocontrol agents. Eleven sites along the Mokolo River and Limpopo River were surveyed. Three randomly selected 0.25m^2 quadrats of giant salvinia biomass were weighed, while 100 plants from the mat were inspected for biocontrol agent damage at each site.

Giant salvinia was discovered at each site with varying levels of cover. The water level was relatively low which created small pools and streams between the reeds in some areas, allowing mats of giant salvinia to collect. In these areas, the weevils were protected, and promoted faster population growth. Biomass measures ranged from 0.32 kg to 8.78 kg per m^2. Damage was discovered at all but one of the inspected sites, and ranged from 10–100% damage.

The biocontrol agents have established successfully throughout the giant salvinia invasion. With more frequent releases to boost the populations, and time, the giant salvinia population will be severely impacted. These weevils will move downstream with the plants into neighbouring countries reducing the impact of the giant salvinia invasions there.

Common Salvinia

RESEARCH TEAM
Prof. Julie Coetzee, David Kinsler, Dr Samuel Motitsoe, Dr Antonella Petruzzella and Samella Ngxande-Koza

COLLABORATORS
Louisiana State University, the African Marine Mammal Conservation Organisation (AMMCO)

South America, has become a significant ecological threat across various water bodies in South Africa. Until 2021, *Salvinia minima* was only found in Hartbeespoort Dam and nearby housing estate ponds, such as The Coves and Lakeland. However, by May 2021, it had spread downstream to Roodekoppies Dam and appeared in two separate systems, Bon Accord and Roodeplaat Dams.

More critically, *Salvinia minima* has been confirmed to be present in the Limpopo River, a transboundary river system stretching into neighbouring countries such as Botswana, Zimbabwe, and Mozambique. Its spread in the Limpopo River poses a serious risk to international water bodies, potentially creating regional conflicts over water resource management. These infestations can also negatively affect agriculture, irrigation, and water supply systems, compounding the challenges faced by communities that rely on these shared water sources.

Salvinia minima is about 2.5 cm deep, with round leaves 1.5–2 cm wide. Its floating leaves have a distinctive rib, giving them a bowl-like shape. The upper leaf surface has hair-like structures that divide into four branches (Figure 19), while the submerged leaves act like roots. As a fern, it does not flower but reproduces through fragmentation, with up to five lateral buds per node. It can grow rapidly, with uncultivated populations doubling every two weeks and, under ideal conditions, every three days.

Salvinia minima's ability to form dense mats on the surface of water bodies severely disrupts aquatic ecosystems by blocking sunlight, reducing oxygen levels, and limiting water flow. This results in the death of native plant and animal species, including fish, thereby impacting biodiversity and local economies reliant on fishing and tourism.

Salvinia minima in South Africa

In June 2024, the Centre for Biological Control (CBC) conducted a field trip to assess the status of *Salvinia minima* infestations in the North West and Limpopo provinces. Along with Hartebeesport Dam (site1), Bon Accord Dam (site 5), Roodeplaat Dam (site 6), and Bronkhortspruit (site 7) the CBC found an additional four river systems infested with *Salvinia minima.*

Figure 19. Hair-like structures of *Salvinia minima*.

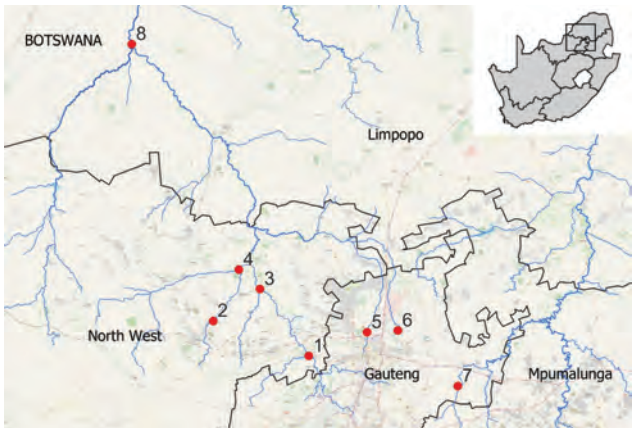

Figure 20. Map of South Africa showing eight known sites invested with Salvinia minima. 1: Hartebeespoort Dam, 2: Bospoort Dam, 3: Roodekoppies Dam, 4: Vaalkop Dam, 5: Bon Accord Dam, 6: Roodeplaat Dam, 7: Bronkhortspruit, 8: Limpopo-Crocodile River confluence.

Figure 21. Salvinia minima on the Bospoort Dam close to the Maletjane Resort.

Figure 22. Salvinia minima infestation along the Hex River approximately 4 km south of the Vaalkop Dam. Photos: Julie Coetzee.

Figure 23. Salvinia minima infestation along the Hex River, just south of the Vaalkop Dam.

Implications for International Water Bodies

The presence of *S. minima* in the Limpopo River poses a significant threat to shared water resources with neighbouring countries. If left uncontrolled, the weed could spread into Botswana, Zimbabwe, and Mozambique, leading to ecological, agricultural, and water supply challenges. These countries rely on the Limpopo River for various critical activities, and the spread of *S. minima* could exacerbate existing pressures on these shared water systems.

Biological Control using Cyrtobagous salviniae

The Centre for Biological Control has been working on biological control options to manage and mitigate this threat. The weevil, *Cyrtobagous salviniae* Calder and Sands (Coleoptera: Curculionidae), (Figure 24) has been tested and proven effective in controlling *S. minima* as it causes significant damage to the fern (Figure 25). The insect feeds on the invasive fern, reducing its biomass and controlling its spread without affecting native species. *Cyrtobagous salviniae* (Florida Biotype) has been approved for release in South Africa to control *S. minima* and has shown strong effectiveness in previous trials.

Despite its approval for release, financial constraints have delayed the mass-rearing process necessary for its widespread deployment. Without sufficient funding, it will be challenging to scale up the production of *Cyrtobagous* to a level where it can be deployed in the field to combat the infestation effectively. Immediate financial support is essential to address this funding gap and prevent further ecological damage.

Figure 24. *Cyrtobagous salvinia* (Florida Biotype).

Figure 25. *Cyrtobagous salvinia* causing damage to *Salvinia minima*.

Figure 26. Mass rearing *Cyrtobagous salvinia* at the Waainek Sisonke Mass-rearing Facility in Makhanda, South Africa.

The June 2024 field trip confirmed that *Salvinia minima* infestations are continuing to spread in several key water bodies in the North West, Limpopo, and Gauteng provinces. Of particular concern is the infestation in the Limpopo River, which poses an immediate risk to neighbouring countries due to its international nature.

To effectively manage the situation, the following steps are recommended:

1. **Funding for biological control**: Allocating resources to mass rear *Cyrtobagous salviniae* to enable its release across all affected regions.
2. **Collaboration with neighbouring countries**: Engaging Botswana, Zimbabwe, and Mozambique in discussions about coordinated control measures for the Limpopo River.
3. **Ongoing monitoring**: Conducting regular site visits and assessments to track the spread of *Salvinia minima* and ensure that biological control efforts are having the desired effect.
4. **Public awareness**: Increasing awareness in affected communities about the impact of aquatic invasive species and encouraging the reporting of infestations.

With the appropriate funding and coordinated action, the Centre for Biological Control can work to contain and ultimately reduce the spread of *Salvinia minima*, protecting South Africa's water bodies and those of our international neighbours

Delta arrowhead

The biological control programme targeting *Sagittaria platyphylla*, one of South Africa's most rapidly expanding invasive species, has shown remarkable progress. Following the initial release of the weevil *Listronotus appendiculatus* in the Makhanda Botanical Gardens in October 2023, 460 adults have since been released at the site. In addition, Dr Daniella Egli (CBC) and Dr Dineshen Singh (UKZN) led a similar effort, releasing 729 adults at Kranzkloof Nature Reserve and Pietermaritzburg Botanical Gardens in the KwaZulu-Natal Province (KZN). An additional release of 50 adults has also been made outside Lourensford Wine Estate in the Western Cape Province.

CBC teams have conducted monthly post-release evaluations to assess the establishment of this agent and track any significant changes in the density of the weed. By March 2024, no adults were observed at the Makhanda Botanical Gardens, suggesting that either the weevils were overwintering in the area or they had died out. However, in October 2024, the weevils were confirmed to have overwintered successfully. Similarly, adult activity at the Pietermaritzburg Botanical Gardens ceased in winter 2024 and resumed in October 2024, suggesting a consistent seasonal overwintering response across different sites. Unfortunately, post-

RESEARCH TEAM
Dr Lenin Chari, Ms Nokuthula Kom, Dr Daniella Egli, Dr Dineshen Singh, Prof. Grant Martin and Prof. Julie Coetzee.

STUDENT
Aviwe May (3rd year)

COLLABORATORS
Nathan Harms (U.S. Army ERDC Environmental Laboratory), Raelene Kwong (Australia's AgriBio Centre for AgriBioscience)

release evaluations at the Krantzkloof Nature Reserve dam were unable to detect the weevil. It is suspected that the lake's maintenance, including draining of the water, may have affected the weevil's establishment. However, prior to the maintenance, the South African National Biodiversity Institute (SANBI) and Ezemvelo KZN Wildlife translocated infested *S. platyphylla* plants from the reserve downstream along the Molweni River within Krantzkloof Nature Reserve and to three additional sites along the Umgeni River. Post-release evaluations have yet to be conducted to determine if the weevil has persisted at these sites. Going forward, both CBC and SANBI will share the responsibility of monitoring and reporting on the biological control programme in KZN.

The latest evaluations in Makhanda Botanical Gardens have indicated that adults have dispersed up to 20 metres upstream from the initial release point, signalling promising establishment and spread. Additionally, preliminary thermal tolerance experiments conducted in the lab by a third-year student, Aviwe May, indicate that the agent is highly tolerant of both heat and cold, suggesting a wide thermal tolerance and a strong potential for establishment across diverse climates. Next year, a postdoctoral fellow will expand on this research to better understand establishment potential and improve predictions for successful distribution.

Listronotus appendiculatus has established at two sites in two provinces, and we hope it will significantly contribute to the management of one of South Africa's worst aquatic weeds.

Figure 27. The weevil, *Listronotus appendiculatus*, in the field in the Makhanda Botanical Gardens in October 2024. Photo: Lenin Chari.

Figure 28. *Listronotus appendiculatus* release at Kranzkloof Nature Reserve. Photos: Daniella Egli.

Yellow Flag Iris

Figure 29. *Aphthona nonstriata* beetles on an *Iris pseudacorus* leaf. Photo: Samella Ngxande-Koza.

RESEARCH TEAM
Prof. Julie Coetzee, Emma Sandenbergh and Samella Ngxande-Koza

Host-specificity testing of indigenous Iridaceae is complete, with candidate biological control agent, *Aphtona nonstriata,* unable to complete its life cycle on any indigenous species. The flea beetle remains in the CBC's quarantine facility to undergo further multi-generational host-specificity testing in the new year. While the release of *A. nonstriata* will pose no risks to native biodiversity, the beetle can develop on exotic *Iris* species which hold potential economic value in South Africa's horticultural industry. The multi-generational host-specificity testing will focus on *Iris* species previously shown to support the development of first-generation beetles. Following the completion of these trials, a release application will be submitted to the DFFE and, if approved, the CBC will release the beetle at invaded sites across South Africa to manage the country's *Iris pseudacorus* invasion.

Amazon Frogbit

Hydrocharis (=Limnobium) laevigata, commonly known as Amazon Frogbit, is a floating aquatic plant native to South America. It has become invasive in regions of Asia, Australia, North America, and Central America. The species forms dense mats that can reduce aquatic biodiversity, disrupt food webs, and restrict access to water bodies such as dams, rivers, and lakes. Recently, it has been recorded in central and southern African countries, including the Democratic Republic of Congo, Zambia, and Zimbabwe. However, its precise distribution and ecological impacts in these areas still need to be qualified.

PhD student, Janet Ncube, conducted a comprehensive study investigating the current geographical distribution and abundance of *H.laevigata* in Zimbabwe. A series of field trips were undertaken to determine the distribution of the weed, and understand its population parameters.

At each site, the following data were recorded: geographic coordinates (altitude, latitude, longitude), presence/absence of *H. laevigata* and plant parameters (height, number of leaves, root length, number of flowers, and number of ramets). Seven sites were selected for sampling to understand the infestation severity. Weed infestation was determined by visual assessment and actual weed counts at the sample point (1m² quadrat). The survey results indicate that *H. laevigata* has established and is a significant invasive weed in Zimbabwe, successfully colonising multiple water bodies. The study confirmed 17 occurrences of *H. laevigata* in five catchment areas of Zimbabwe: Manyame, Save, Sanyati, and Mazowe, while it was notably absent from the Gwayi and Mzingwane catchments.

RESEARCH TEAM
Prof. Martin Hill, Prof. Julie Coetzee and Dr Gerald Chikowore

STUDENT
Janet Ncube (PhD)

COLLABORATOR
CABI - Switzerland, FUEDEI

Most of the water bodies within these catchments exhibited severe levels of infestation. Water bodies near urban areas, such as Harava Dam in Chitungwiza and Nyadire Dam in Mutoko, were heavily infested with *H. laevigata*. Sewage discharged into these water bodies created ideal conditions for the weed's growth, fostering eutrophication and an environment conducive to its rapid spread and dominance. Similarly, Muchekeranwa and Reinfield dams exhibited severe infestations attributed to fertiliser runoff from adjacent farms. The influx of nutrients created an ideal environment for the weed's growth, contributing to dense infestation and potentially harming the aquatic ecosystem.

The study found substantial differences in *H. laevigata* density, ranging from 110 plants/m² to 612 plants/m². Weed frequency varied across survey sites, with the highest frequencies observed in some sampled sites. The higher frequency and density of *H. laevigata* directly contributed to its increased abundance, with five of the seven surveyed water bodies exhibiting elevated abundance levels.

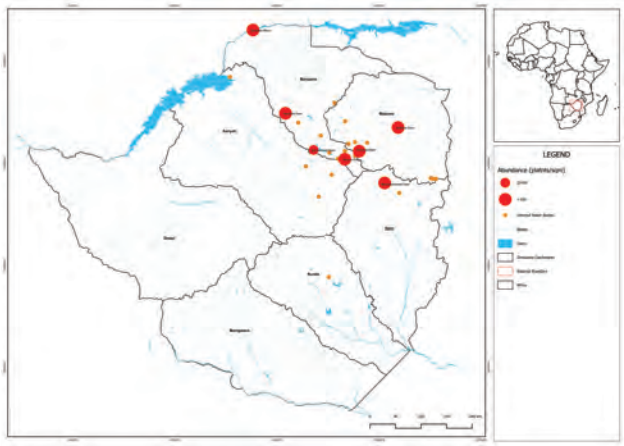

Figure 30. Current distribution map of *Hydrocharis laevigata* in Zimbabwe.

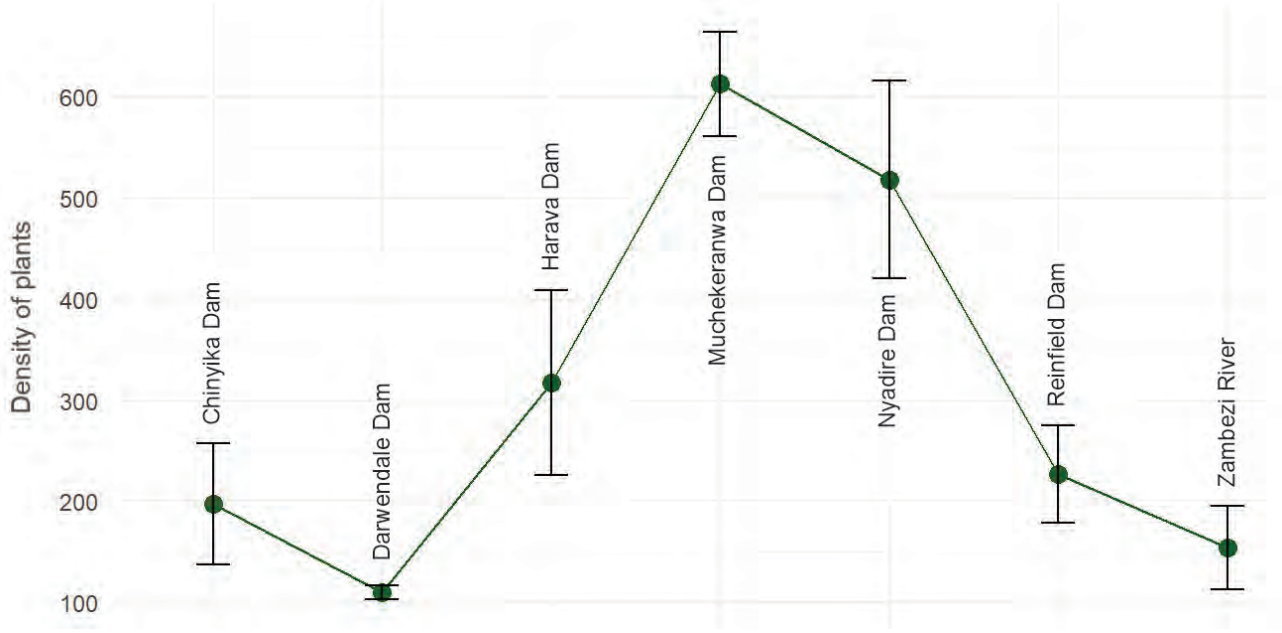

Figure 31. Mean plant densities of *Hydrocharis laevigata* from sampled water bodies in Zimbabwe (m^{-2})

MOZiMACs: Invasive aquatic plants and mosquito proliferation in water ecosystems

Floating invasive alien plants (IAPs) have negative effects on biodiversity and, while this overall trend is true, some exceptional species may benefit from the presence of these plants. Mosquitos, of which South Africa has native and invasive species, are known vectors of disease and, therefore, of concern regarding public health. MOZiMACs is a new international project that aims to understand the interaction between invasive aquatic plants and mosquitoes. Combining field observational studies with controlled experiments and species distribution modelling, we will explore how the presence and subsequent control of floating IAPs influences mosquitoes' colonisation, reproduction and survival/mortality rates. Using social science methods, the project will also explore people's perceptions, knowledge and understanding of the potential links between IAPs and mosquitos in areas with and without an established history of mosquito-borne diseases. Many of the floating IAPs that have been problematic in southern Africa for a long time are now spreading throughout Europe, a trend that will likely increase under climate change. Both these regions lack any native floating plants, so the presence of IAPs provide novel habitats which could alter current mosquito distributions and dynamics.

RESEARCH TEAM
Prof. Julie Coetzee, Prof. Ryan Wasserman and Prof. Emily Strange (Leiden University)

STUDENTS
Thoriso Masalesa (MSc), Hlumelo Mantshi (MSc) and Tressia Chikodza (PhD)

COLLABORATORS
Prof. Maarten Schraama (Leiden University) and Dr Ross Cuthbert (Queens University, Belfast)

Mosquito abundance and species composition

Tressia Chikodza, a joint PhD candidate at the CBC and WildCoLab at Leiden University in the Netherlands, is investigating the role of IAPs in influencing mosquito abundance and species composition, focusing on South Africa and Europe. Her research aims to (1) assess local community perceptions of mosquitoes, diseases (such as malaria), and breeding habitats, including any connection to IAPs; (2) conduct field studies to quantify mosquito abundances and species composition in invaded vs non-invaded sites in Europe and South Africa; and (3) develop species distribution models for selected mosquito and IAP species based on their climatic suitability. The findings of this study will provide insights into the influence of IAPs on mosquito populations across different regions, supporting effective management strategies to control both invasive plants and mosquitoes.

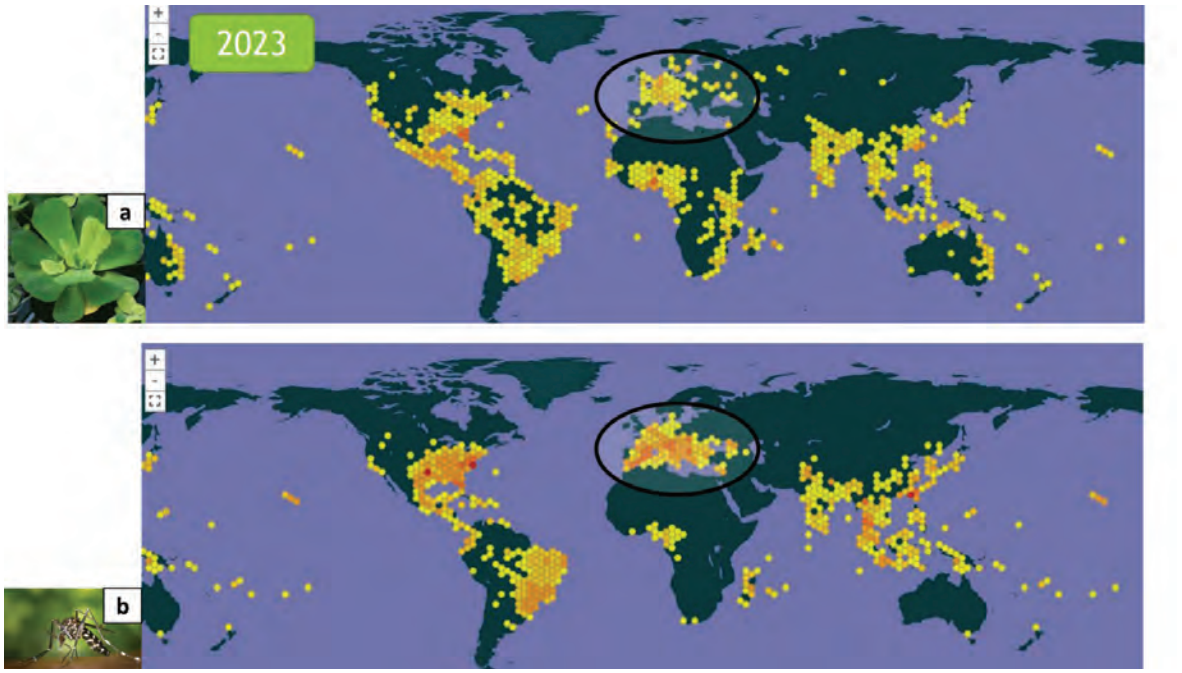

Figure 32. (a) Map showing the spread of *Pistia stratiotes* across Europe. (b) Map showing the spread of *Aedes albopictus* across Europe. Source: GBIF, E. Strange.

Impact of Invasive Aquatic Plants on Mosquito Ecology and Predator Dynamics

Global warming is compounding the spread of many floating aquatic invasive alien plants (IAPs). Floating IAPs alter shallow lentic limnological characteristics, with implications for light levels and thermal dynamics. There is also evidence that these IAPs facilitate the proliferation of mosquitoes, a group considered among the most critical biological enemies of humans and animals, given their vectorial capacity for many diseases. Microclimate and microhabitat modifications have implications for organismal fitness and predator-prey interaction outcomes.

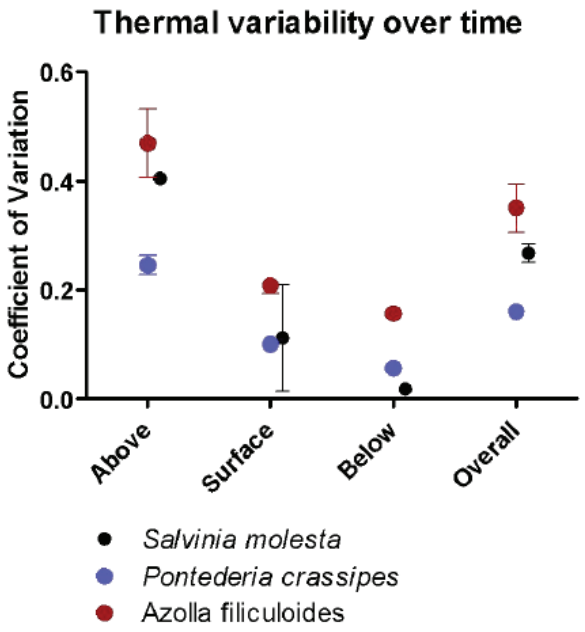

Figure 33. Variability in microclimate temperatures in mats of *Salvinia molesta*, *Pontederia crassipes* and *Azolla filiculoides*, at different positions in the water column.

Hlumelo Mantshi, an MSc student, is working on understanding these dynamics. His research explores the development times and size-at-pupation, or compensatory growth, of *Culex pipiens* (Culicidae) reared under different temperature and shading regimes. It also examines predator-prey interaction dynamics between *Anisops debilis* (Notonectidae) and *C. pipiens* across these temperature and shading conditions, using a functional response approach to analyse density-dependent predation across various instars of *C. pipiens*, focusing on size-specific predation. The first step in this study was to understand differences in microclimate temperatures in mats of common aquatic weeds. Results showed that *P. crassipes* had less variability in microclimate temperatures above the water surface than *S. molesta* or *A. filiculoides,* while temperatures in *A. filiculoides* mats were more variable at the surface and below. This suggests that *P. crassipes* and *S. molesta* buffer water temperatures to a greater degree than *A. filiculoides* which will have consequences for adult oviposition choice, and larval development times.

The findings from this research will contribute to a model that explores how compensatory growth and density- and size-specific predation interact under different temperature and shading regimes, potentially facilitating the proliferation of *C. pipiens* populations. This work will provide insights into the interactions between invasive aquatic weeds and *Culex* mosquitoes, helping to address whether invasive aquatic weeds create conditions that facilitate mosquito invasions.

Fieldwork includes the use of temperature loggers to monitor the effects of invasive aquatic weeds on water thermodynamics and to understand how temperature shifts influence the development of mosquito larvae. Additionally, mosquito traps for adults are being deployed in water bodies with varying levels of weed infestation to monitor mosquito abundance and diversity. Sampling of aquatic macroinvertebrates, particularly predators, is also being conducted to investigate the effect of floating IAPs on predator dynamics.

Floating aquatic alien invasive plant species have varying implications for mosquito predation risk

Thoriso Masalesa, an MSc student, is investigating how invasive aquatic plants influence predator-prey dynamics between backswimmers and mosquitoes in aquatic ecosystems. These ecosystems are rich in life and interactions, including the critical relationship between predators like backswimmers and their prey, mosquito larvae. Thoriso's study explores whether invasive aquatic plants provide mosquito larvae with hiding spots, potentially reducing their visibility to predators and altering this balance.

In controlled experiments, Thoriso used *Anisops sardius*, a species of backswimmer, to assess its ability to prey on mosquito larvae in environments featuring different plant types. Five conditions were established: water hyacinth, parrot's feather, red water fern, native duckweed, and a no-plant control. The objective was to determine if dense, complex plants like water hyacinth hinder the backswimmer's ability to locate and prey on mosquito larvae. Over time, predation rates were recorded for each condition.

Figure 34. A water hyacinth invasion on the Schoonspruit, North West Province, teeming with mosquitoes.

The results revealed notable patterns. In environments with dense vegetation, such as water hyacinth and parrot's feather, *Anisops sardius* struggled to capture mosquito larvae, with predation rates falling below 25%. Conversely, in conditions with red water fern, duckweed, or no plants, backswimmers demonstrated higher predation efficiency, consuming over 50% of the larvae. Dense plants, like water hyacinth, were observed to block light and reduce visibility, making it challenging for visually dependent predators to locate their prey.

Figure 35. Predator behaviour experiment set up in a controlled environment room at the Rhodes University Department of Zoology and Entomology. Photo: Ryan J Wasserman, September 2024.

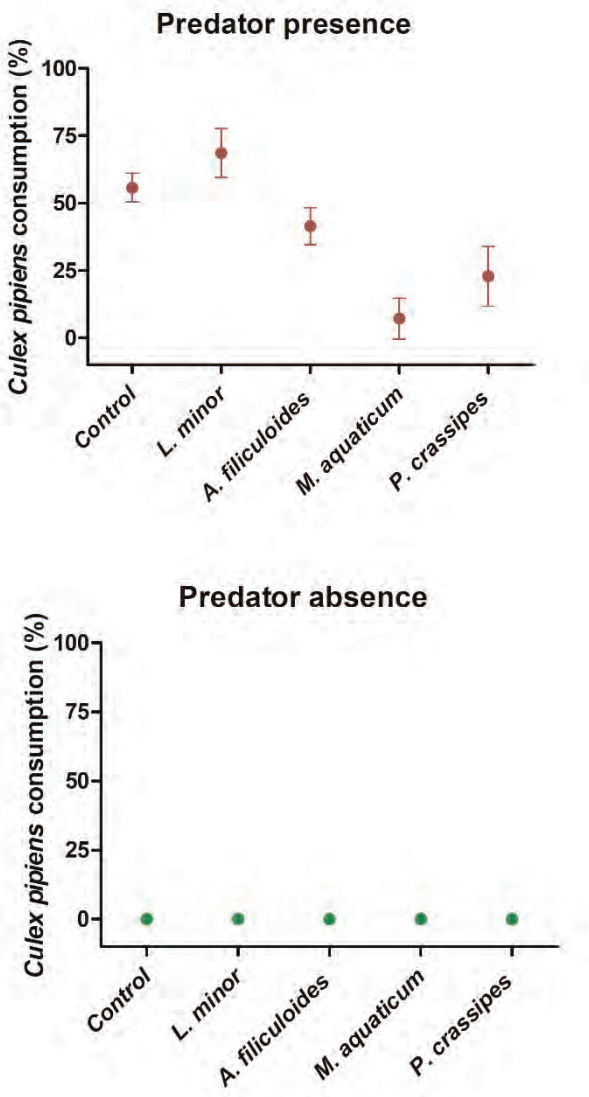

Figure 36. Mean (± standard deviation) proportional consumption of *Culex pipiens* larvae prey from each chamber under predator (Hemiptera: *Anisops debilis*) and predator-free scenarios. Control = no plant cover, *L. minor* = *Lemna minor* (common duckweed), *A. filiculoides* = *Azolla filiculoides* (red water fern), *M. aquaticum* = *Myriophyllum aquaticum* (parrot's feather), *Po. crassipes* = *Pontederia crassipes* (water hyacinth).

Thoriso's findings suggest that invasive plants with thick foliage and extensive root systems create safe havens for mosquito larvae by limiting predator effectiveness. These results have significant implications for mosquito control, as invasive plants may indirectly increase mosquito populations by reducing natural predation. This underscores the need for ecological management strategies to mitigate the effects of invasive aquatic plants, not only to restore ecosystem balance but also to reduce potential public health risks posed by mosquito-borne diseases.

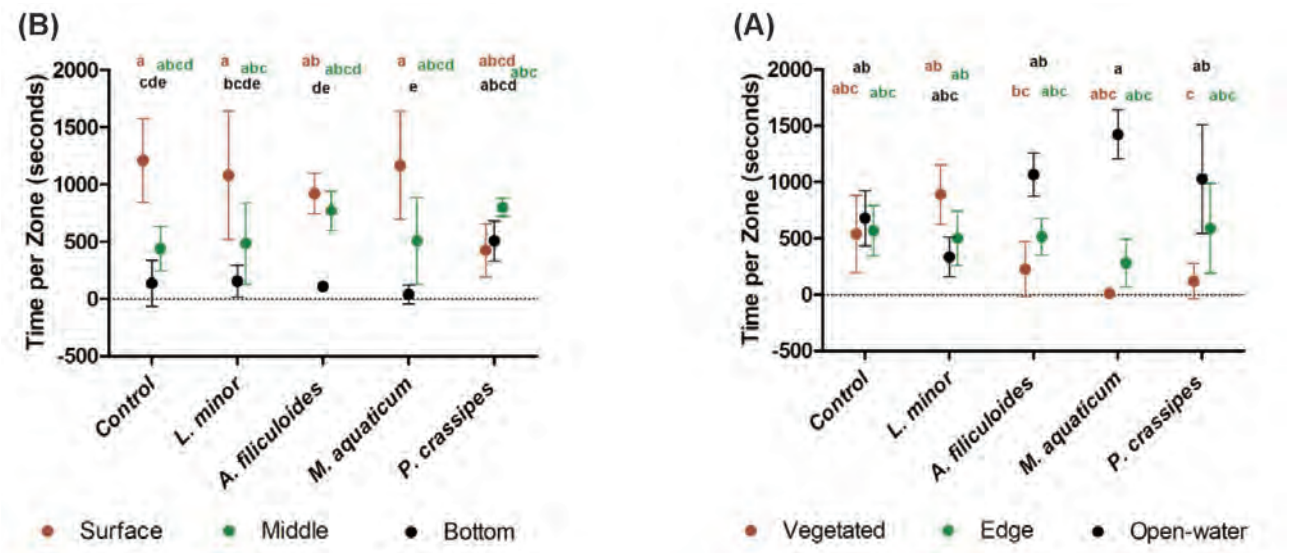

Figure 37. A: Mean (± standard deviation) of time in seconds that the predator (*Hemiptera: Anisops debilis*) spent in each vertical (A), and horizontal (B) zone of the tank.). Control = no plant cover, *A. filiculoides* = *Azolla filiculoides* (red water fern), *L. minor* = *Lemna minor* (common duckweed), *M. aquaticum* = *Myriophyllum aquaticum* (parrot's feather), *Po. crassipes* = *Pontederia crassipes* (water hyacinth). Letters denote significant homogenous groups as identified by the GLM Post-hoc comparisons, colour coordinated per zone within each treatment.

Ecological Restoration

The presence of alien invasive macrophytes in aquatic ecosystems continues to threaten biodiversity and the stability of these environments. Current management strategies, such as mechanical and biological control, provide only temporary improvements in water quality and ecosystem health. To achieve lasting recovery, however, a more comprehensive restoration approach is essential especially in light of the UN Decade on Ecosystem Restoration (2021–2030), which offers a critical opportunity to rethink how we restore aquatic systems impacted by invasive species.

Recent research by the CBC restoration team has brought attention to a key phase following the removal of invasive free-floating aquatic weeds: a unique window for intervening to promote holistic ecosystem recovery. This phase is crucial for building resilience against re-invasion and secondary invasions, a common issue in disturbed aquatic environments like those in South Africa.

The CBC has been a leader in studying the management of invasive macrophytes, setting important precedents for integrating these efforts into broader ecosystem restoration initiatives. One notable breakthrough is the use of aquatic macroinvertebrates as biological indicators of recovery, offering high-resolution insights into the ecological disruptions caused by invasive species. Studies have shown that invasive macrophytes reduce biodiversity, diminish resource availability, and homogenise functional diversity, leading to ecosystem collapse if left unmanaged.

In addition to monitoring lower trophic levels such as phytoplankton and zooplankton, the team is investigating how plant identity and diversity affect the success of re-vegetation after biological control of invasive species. These findings will help design more effective active restoration strategies, focusing on the plant species best suited to restore functional diversity and ecosystem resilience.

RESEARCH TEAM
Dr Samuel Motitsoe, Dr Antonella Petruzzella, Dr Emily Strange, Prof. Julie Coetzee and Prof. Martin Hill

STUDENTS
Lulutho Mancunga (MSc), Eva Rekkers (MSc), Hlumelo Mantshi (Hons), Naledi Moteka (MSc) and Elizabeth Magadzi (MSc)

COLLABORATORS
School of Animal, Plant and Environmental Science, Wits University; Leibniz-Institute of Freshwater Ecology and Inland Fisheries; Leiden Universiteit, Netherlands; Department of Zoology and Entomology, Rhodes University, and South Africa Institute of Aquatic Biodiversity

This work is ongoing, with a pivotal study launched in 2022. In this experiment, the CBC replicated an ecosystem invaded by *Pistia stratiotes* (water lettuce) and released the biological control agent, *Neohydronomus affinis*, to study its effects. After the removal of the invasive species, native macrophytes were introduced to: (1) increase ecological resilience, (2) test the role of plant identity and diversity in preventing secondary invasions, and (3) understand how the timing of invader arrival affects restoration success. This research, potentially the first of its kind globally, will inform restoration practices in the South African context and beyond.

Additionally, the CBC believes that the impact of invasive species extends far beyond what is visible. Emerging technologies such as trophic ecology, functional diversity indices, expose damage caused by invasive species; they may be ideal tools to reveal the recovery potential of ecosystems after control efforts also for shedding light on the facilitation of secondary invasions.

Ultimately, this research has advanced our understanding of invasive species management and provided actionable insights into the most effective control methods be they biological, mechanical, or integrated approaches. As we continue our work within the framework of the UN Decade of Ecosystem Restoration, these findings contribute to the development of long-term, sustainable strategies that can restore ecosystem function and biodiversity. The question now is how to leverage these insights to create scalable, impactful restoration efforts that will enhance biodiversity and resilience for future generations.

Mass Rearing

The Waainek Mass-Rearing Facility provides biological control agents for waterweeds across the country. Numerous requests for the planthopper, *Megamelus scutellaris,* for *Pontederia crassipes* and the weevil, *Neohydronomus affinis,* for *Pistia stratiotes* have been received from Gauteng Province this year for release mainly on the Vaal River, through a contract with the CBC has with Rand Water. Rand Water and the community around the Vaal River Barrage have set up satellite rearing stations to mass rear these two agents. Rand Water staff received training by the CBC at the Waainek Mass-Rearing Facility to optimise their mass rearing for effective and timely control of the Vaal Barrage weeds.

FACILITY TEAM
Samella Ngxande-Koza, Nokuthula Kom Landile Booi, Lyle Titus, Mthobeli Mvandaba, Siyaxolisa Mini, Nandipha Ngolothi, Siyanda Ntamo and Vuyani Ntyinkala

Salvinia molesta, is a major problem on the Mokolo River in Lephalale, Limpopo, and thus there has been high demand for the biocontrol agent, *Cyrtobagous salviniae*. We have continued releasing agents for control of aquatic weeds when required to by the public, or government stakeholders.

Table 1. The number of biological control agents released from the Waainek mass-rearing facility in 2024

Weed	Agent	Number of releases made	Total number of insects or larvae released
Pontederia crassipes	*Megamelus scutellaris*	44	240 000
Myriophyllum aquaticum	*Lysathia sp.*	3	1350
Egeria densa	*Hydrellia egeriae*	1	2700
Pistia stratiotes	*Neohydronomus affinis*	21	17 620
Salvinia molesta	*Cyrtobagous salviniae*	10	8850
Sagittaria platyphylla	*Listronotus appendiculatus*	2	303
TOTAL		81	270 823

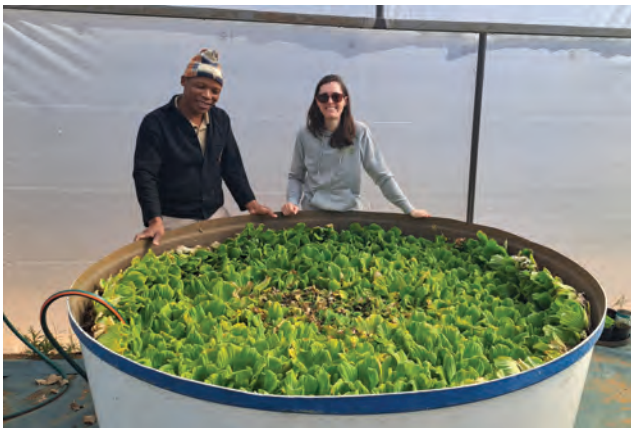

Figure 38. CBC staff assisting with mass rearing of water hyacinth and water lettuce biological control agents at Rand Water's new mass rearing facility in Eikenhof, south of Johannesburg.

Figure 39. Dr Kelby English visiting community rearing stations on the Vaal River, where local stakeholders set up tunnels, at their expense, to rear water lettuce and water hyacinth control agents. Photos: Julie Coetzee.

CACTACEAE WEEDS

Cactus weeds are some of the most problematic invasive alien plants in Africa. They form dense spiny thickets that reduce the carrying capacity of rangelands, restrict the movement of livestock and wildlife, and negatively impact indigenous biodiversity. Biological control is an effective solution to this problem, and the CBC works to implement biocontrol of cactus weeds as well as develop agents for new cactus targets.

In 2024 the focus of the cactus biocontrol programme has been on the development of new agents for torch cactus, *Trichocereus spachinanus*, and thistle cactus, *Cylindropuntia pallida*. These are both serious agricultural pests that can restrict the access of livestock and wildlife to grazing and shade, both essential for the survival of these animals in the hot arid parts of South Africa.

A cochineal insect called *Dactylopius confertus* is currently being evaluated as a potential biocontrol agent for torch cactus. Pre-release impact assessments have shown that it is suitably damaging to warrant release, and host specificity testing has indicated that it is restricted to a group of closely related species within the family Cactaceae, none of which are of commercial value or are indigenous. The final stages of host specificity testing are underway and hopefully we can apply for release of this new agent in 2025.

Thistle cholla is successfully controlled by a cochineal, *Dactylopius tomentosus* californica var parkeri, in Australia, but our studies have shown that the cochineal used in Australia is not effective against South African thistle cholla plants. A new cochineal, *D. tomentosus* pallida, has been imported from Mexico and has proven to be damaging to the South Africa populations of the target plant. Host specificity testing of this cochineal is currently underway.

The Kareiga mass-rearing team has continues to release cactus biocontrol agents throughout South Africa, ensuring that the right agent is released on the right plant, and that cactus biocontrol agents are present wherever they are required. This has significantly benefited farmers as well as indigenous ecosystems in the country. Hopefully the new agents for torch cactus will be added to the list of agents mass-reared at the facility soon.

PROGRAMME HIGHLIGHTS IN 2024

- A new biocontrol agent for thistle cholla, *Cylindropuntia pallida*, has been imported into quarantine from Mexico. It is a lineage of *Dactylopius tomentosus* that is particularly damaging to South African thistle cholla, and is likely to be an effective agent.
- After testing six lineages of the mealybug, *Hypogeococcus,* that were collected in Argentina, none proved effective against torch cactus, *Trichocereus spachianus*. But a cochineal insect of South American origin, *Dactylopius confertus*, is proving to be damaging and suitably host specific against this target weed.
- Almost six-hundred releases of cactus agents have now been conducted by the CBC in every province of the country. These releases have had significant benefits for land users and natural ecosystems.

Thistle cholla

Cylindropuntia pallida, commonly known as the Thistle cholla, has become a problematic invasive weed in parts of South Africa, Australia, Saudi Arabia, Spain, and Namibia. The cladodes of *C. pallida* can easily fall off the main plant and be carried away by vectors, such as vehicle tyres and animal fur, allowing their populations to spread. Like other invasive cactus species, the plant becomes overabundant and has large spines that are harmful to livestock, and are contaminants of wool, which reduces yields of wool and mohair for local farmers. The spiny thickets that form in areas with *C. pallida* infestations restrict human and animal movement, reducing access to grazing, shade, and water sources. Not only do they restrict animal movement, but they can also be dangerous as they can impale animals with their spines. Further to these issues, *C. pallida* can outcompete native species and become a threat to indigenous biodiversity and ecosystem functioning. In South Africa, *C. pallida* has invaded many areas of agricultural land in the Eastern Cape and was initially controlled chemically, which reduced numbers at most sites where it had been recorded. However, this proved to be ineffective in the long term as complete eradication from sites was rare, with regrowth occurring even after multiple follow-up treatments.

RESEARCH TEAM
Pippa Muskett and Iain Paterson

STUDENT
Wade Sexton (Msc)

COLLABORATORS
Liberato Portilla and Ana-Lilia Vigueras (University of Guadalajara); Andrew McConnachie (NSW DPI)

Figure 40. Wade Sexton collecting cladodes for testing in Cradock, Eastern Cape. Photo: Pippa Muskett.

Figure 41. A settled crawler on a South African *C. pallida* plant. Photo: David Taylor.

In Australia, researchers began searching for an option for biological control. A cochineal lineage called *Dactylopius tomentosus* 'californica var. parkeri' was collected from Baja California, Mexico from the cactus species *Cylindropuntia bernardina,* formerly *Cylindropuntia californica* var. *parkeri*. Host-specificity testing conducted in Australia showed that it was a suitable and effective agent for *C. pallida* in Australia. This resulted in the agent's release and it has been extremely effective in reducing *C. pallida* infestations in Australia. Owing to the success of the agent in Australia, the release of *D. tomentosus* 'californica var. parkeri' was approved for release in South Africa. However, after three unsuccessful attempts to rear the agent on South African plants in quarantine at the Centre for Biological Control (CBC), the possibility of the South African plants being unsuitable hosts was considered. Given the unsuccessful attempts to rear *D. tomentosus* 'californica var. parkeri' on South African *C. pallida* plants, fitness, and fecundity testing was conducted on both Australian and South African *C. pallida* so a comparison could be made. A second cochineal lineage called *D. tomentosus* 'pallida' was also collected off *C. pallida* in its native distribution of Hidalgo, Mexico. Thanks to our collaboration with two researchers, Liberato Portilla and Ana-Lilia Vigueras from the University of Guadalajara, we were able to survey multiple sites in Hidalgo, Mexico, in search of cochineal on *Cylindropuntia pallida*.

For his Masters, Wade has tested the compatibility of the cochineal lineages with invasive *C. pallida* from South Africa by comparing cochineal fitness parameters when reared on the South African *C. pallida* or control plants (either Australian *C. pallida* or Mexican *C. pallida*). Ten crawlers were inoculated onto each of the controls and the South African cladodes. Measurements were taken to assess fitness, which included female mass, settlement and female fecundity. The 'californica var. parkeri' lineage developed and reproduced effectively on Australian plants but had significantly lower survival rates, longer duration of development, and lower fecundity on South African *C. pallida.* The 'pallida' lineage had greater survival and fecundity on South African plants than on Mexican plants. The results indicate that the 'californica var. parkeri' lineage is incompatible with the *C. pallida* plants in South Africa. The 'pallida' lineage is compatible with South Africa *C. pallida* and should be considered further as a potential agent.

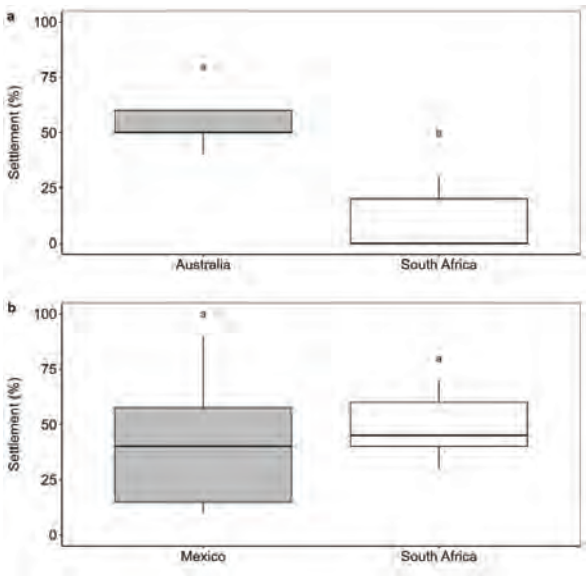

Figure 42. a.) Mean (±S.E) settlement percentage of crawlers of *Dactylopius tomentosus* 'californica var. parkeri' on Australian and South African *Cylindropuntia pallida* and (b.) Mean (±S.E) *D. tomentosus* 'pallida' lineage on Mexican and South African *C. pallida*. Different lower case letters indicate significant difference between groups (P< 0.05).

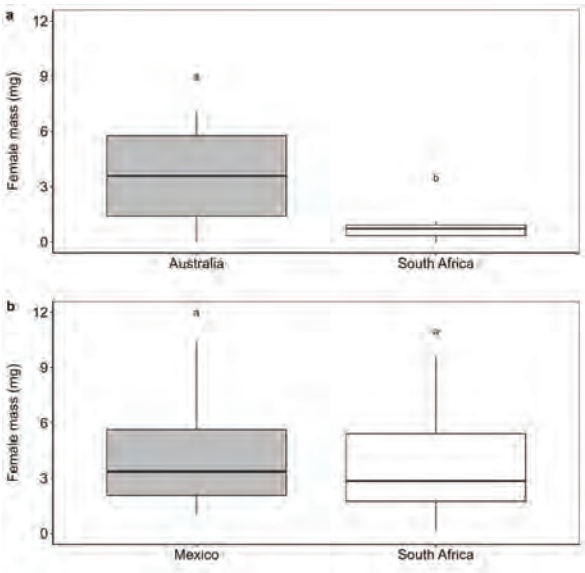

Figure 43. a) Mean female mass (mg) of *Dactylopius tomentosus* 'californica var. parkeri' on Australian and South African *Cylindropuntia pallida* and (b.) Mean (±S.E) female mass (mg) of *D. tomentosus* 'pallida' on Mexican and South African *C. pallida*. Different lower case letters indicate significant difference between groups ($P < 0.05$).

A 'new association' in biocontrol is defined as a species that attacks a target weed which it has not co-evolved with (like 'californica var. parkeri' on *C. pallida*). 'Old associations' are those where the biocontrol agent and weed have a long-standing evolutionary relationship (like 'pallida' on *C. pallida*). To date, no studies have been done to determine if there is a trend between the phylogenetic relationship of the plant species and the performance of certain biocontrol agents, and whether they perform better on 'newer' or 'older' associations. To test this, we assessed the fitness and performance of three *D. tomentosus* cochineal lineages ('pallida', 'imbricata', and 'cholla') on seven different invasive *Cylindropuntia* species present in South Africa and aimed to assess whether fitness and performance decrease with more genetically distant plant species from the primary host plant. For every fitness performance metric tested in this study, we found a correlation between phylogenetic distance and performance, with fitness measurements decreasing for each cochineal lineage on less closely related species. This study provides evidence that 'old associations' are better for biocontrol agent selection, and it has major implications for how we can select and prioritise agents in the future.

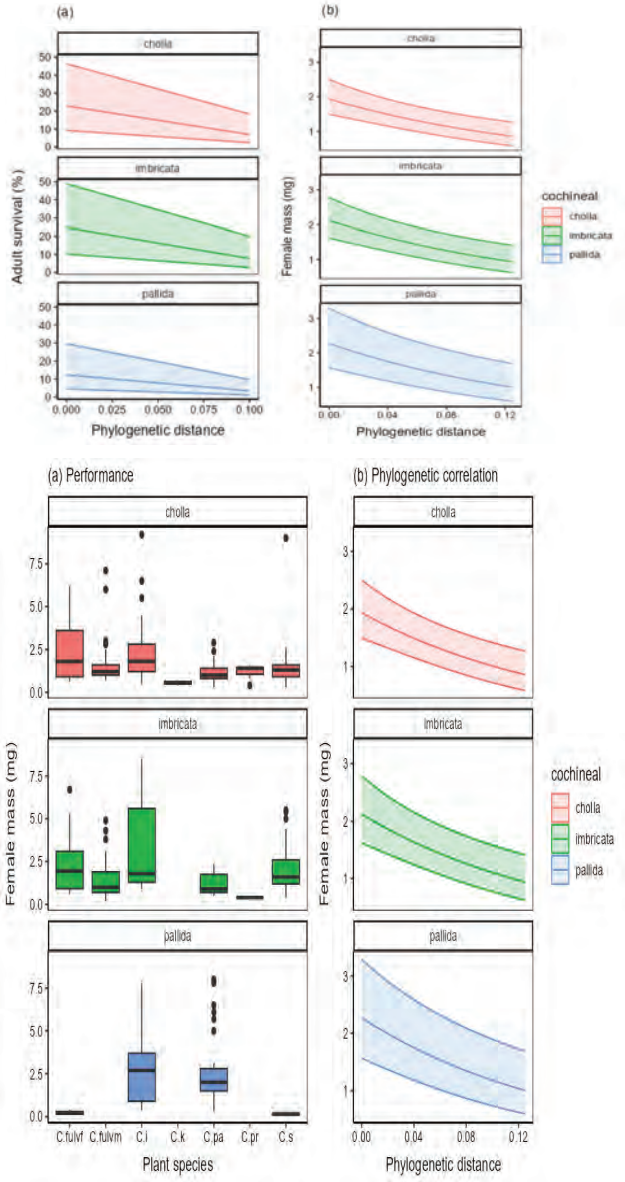

Figure 44. a.) Marginal effects showing the correlation between phylogenetic distance from the original host plant and adult survival (%), and b.) female mass (mg) for each cochineal lineage. The coloured line represents the mean expected female mass (mg) per female, and the shaded area represents the 95% confidence interval of the mean.

Round-leaf tuna cactus

Round-leaf tuna cactus, *Opuntia megapotamica,* was correctly identified in South Africa in 2021 but the plant has been present in South Africa since the 1930s. The infestations have remained concentrated in the Eastern Cape, but are dense and problematic, negatively affecting the carrying capacity of farmlands. *Dactylopius opuntiae,* which is released across South Africa to control *Opuntia ficus-indica* and *O. stricta,* has been recorded on *O. megapotamica,* but is not reported to control it effectively. When *Opuntia megapotamica* was incorrectly identified as a subspecies of *Opuntia engelmannii,* attempts to find a biological control agent to control it were made using this identification, which meant that there was a focus on testing cochineals from North America, because *O. engelmannii* is a North American cactus species. The plant has now been correctly identified as *O. megapotamica*, and investigations have focused on which of two new cochineal species in quarantine (one North American and one South American) would be more effective than the lineages of cochineal already released in South Africa.

To justify the release of a new lineage of cochineal as a biological control agent for *O. megapotamica,* it would need to be as effective as other cochineal lineages being considered, and more effective at controlling *O. megapotamica* than any of the lineages already released in South Africa. To test this, insect fitness data were collected when the two new cochineal lineages (*Dactylopius opuntiae* 'engelmannii' and *Dactylopius ceylonicus* 'rioplatense') and four other cochineal species already released in South Africa were fed *O. megapotamica,* compared to when the cochineal were fed their intended target species. Another trial was also conducted to see how fast the different cochineals were able to kill *O. megapotamica* plants compared to the speed that a well-known, effective cochineal lineage is able to kill its host (*D. ceylonicus* on *O. monacantha*).

RESEARCH TEAM
Prof. Iain Paterson and Pippa Muskett

COLLABORATORS
Wits University (Nic Venter and Samalesu Mayonde), ARC-PPRI (Kedibone Mofokeng)

When comparing cochineal, it is standard practice to calculate a fitness index when they are fed different host plants. *Dactylopius ceylonicus* 'rioplatense' had a significantly higher average fitness index on *O. megapotamica* compared to the other cochineal lineages, and it did not differ significantly with the control combination (Figure 46). The probability of survival for *O. megapotamica* became less than 1 % a month faster when it was infested with *D. ceylonicus* 'rioplatense' than the next most effective lineage of cochineal, *D. opuntiae* 'stricta', and the control reached the same stage two weeks after *D. ceylonicus* 'rioplatense' on *O. megapotamica* (Figure 46). These results indicate that *D. ceylonicus* 'rioplatense' could be an effective biological control agent for *O. megapotamica,* but *D. opuntiae* 'stricta', which is already released in South Africa, was not significantly different from it. This suggests that it might be worth doing augmented releases of *D. opuntiae* 'stricta' to areas where the infestations are problematic rather than spending the money and time to carry out host-specificity and hybridisation testing to ensure that the new cochineal is safe to release in South Africa.

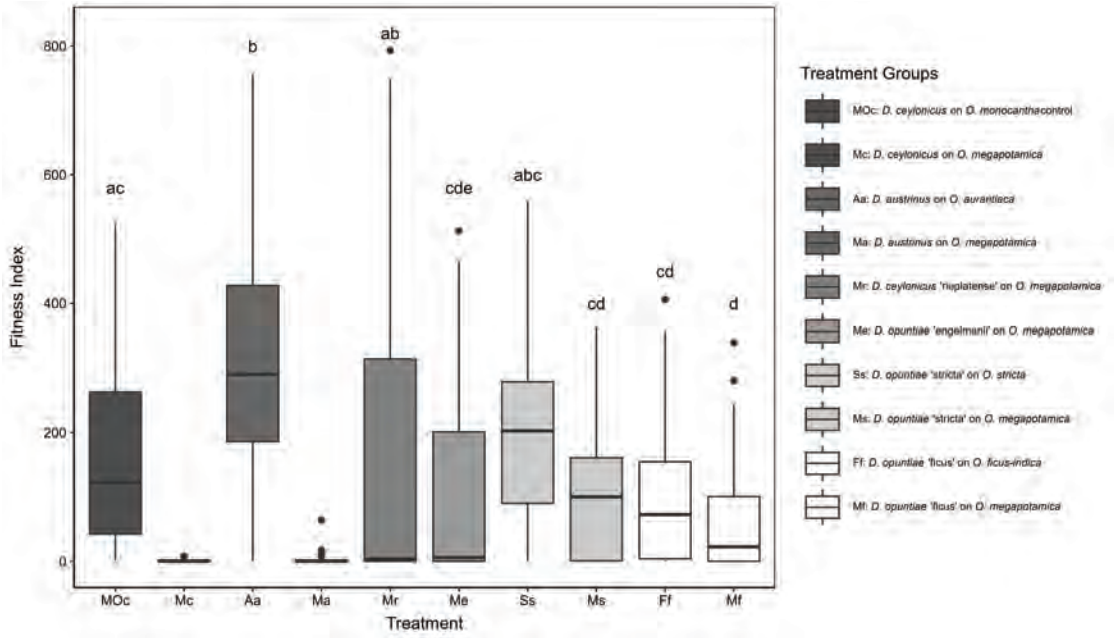

Figure 45. Fitness index calculations (survival to second instar x progeny/developmental time) for each of the cochineal and Cactaceae combinations (*D. ceylonicus* on *O. monacantha*, *D. ceylonicus* on *O. megapotamica*, *D. austrinus* on *O. aurantiaca, D. austrinus* on *O. megapotamica*, *D. ceylonicus* 'rioplatense' on *O. megapotamica*, *D. opuntiae 'engelmannii'* on *O. megapotamica*, *D. opuntiae* 'stricta' on *O. stricta*, *D. opuntiae* 'stricta' on *O. megapotamica*, *D. opuntiae* 'ficus' on *O. ficus-indica* and *D. opuntiae* 'ficus' on *O. megapotamica*). There was a significant difference ($P < 0.0001$) found between some of the treatments as indicated by the letters above each treatment. *D. ceylonicus* on *O. megapotamica* and *D. opuntiae 'engelmannii'* on *O. megapotamica* were not included in the analysis because they did not establish.

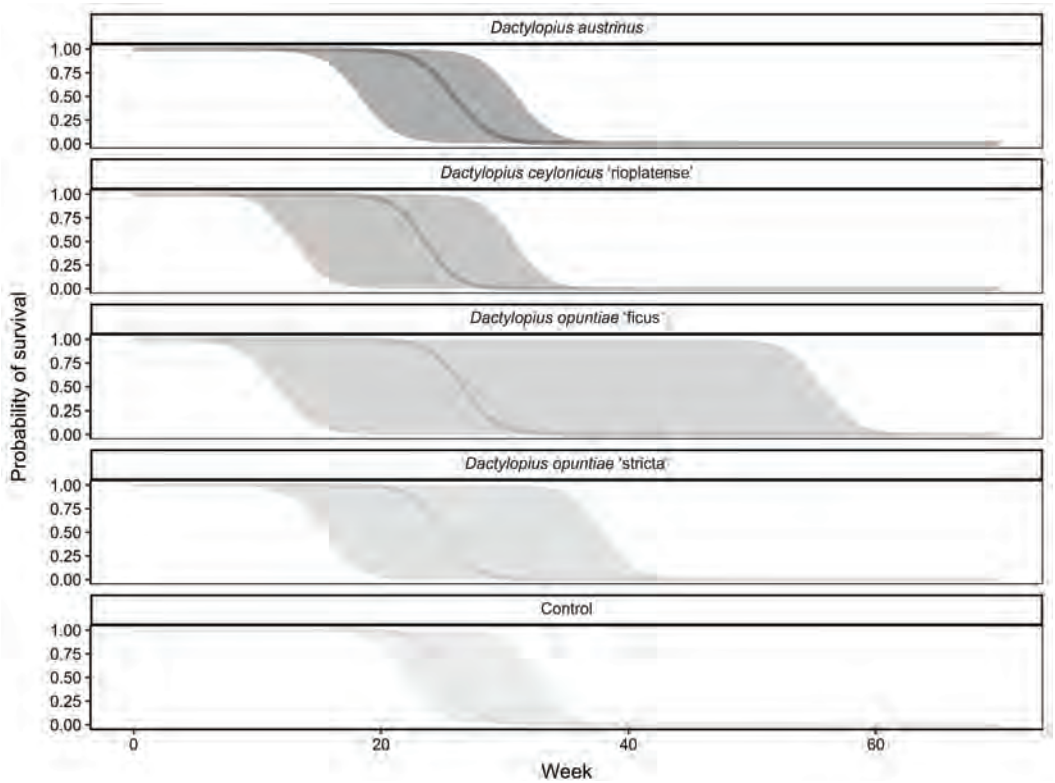

Figure 46. The mean probability of survival of *Opuntia megapotamica* plants over 70 weeks, for the three species of cochineal that successfully established on *Opuntia megapotamica* (*Dactylopius austrinus*, *Dactylopius opuntiae* 'ficus' and *Dactylopius opuntiae* 'stricta') and the control which is *Dactylopius ceylonicus* on *Opuntia monacantha*. The shaded ribbon represents the 95% confidence interval of the mean marginal expected value.

Orange tuna cactus

Since 2017, *Opuntia elata*, otherwise known as Orange tuna cactus, has been a target for early preventative action, and research has been underway to find an effective biological control agent to control it. This was prioritised because there was a sharp increase in *O. elata* across the country and it shares characteristics with many closely related species which have become invasive. A survey of the known *O. elata* sites in South Africa, conducted in 2019, confirmed that *O. elata* infestations were already becoming dense and problematic. Finding an effective biological control agent for *O. elata* in the early stages of the invasion could prevent the plant from spreading further and reduce the cost of control.

There are some lineages of cochineal released as biological control agents in South Africa that control more than one species of Cactaceae, but surveys in South Africa appeared to confirm that none of the lineages of cochineal already released in South Africa were using *O. elata* as a host. It was then a surprise during a damage trial when *Dactylopius austrinus,* which is used to control *Opuntia aurantiaca,* was able to establish and kill *O. elata* at a similar rate as *Dactylopius ceylonicus* kills *Opuntia monacantha. Dactylopius ceylonicus* is an extremely effective biocontrol agent against *O. monacantha,* so similar levels of damage indicate that another agent-plant combination is likely to be successful. This suggests the possibility that *D. austrinus* has potential as a biological control agent for *O. elata*.

Surveys were also conducted in the plant's native distribution (Argentina) for a new lineage of cochineal. *Dactylopius ceylonicus* 'rioplatense' was collected off *Opuntia rioplatense*, a close relative of *O. elata*, and brought back into quarantine in South Africa. The ability of *Dactylopius ceylonicus* 'rioplatense' and *D. austrinus* to survive and reproduce on *O. elata* was then compared and no significant difference found between them. There was, however, significant variation in how damaging the *D. austrinus* cochineal was on different *O. elata* plants.

RESEARCH TEAM
Prof. Iain Paterson and Pippa Muskett

COLLABORATOR
FuEDEI

Comparison of insect fitness showed that neither *D. austrinus* nor *D. ceylonicus* 'rioplatense' were significantly more effective than *D. austrinus* on its primary host plant *O. aurantiaca*, and neither cochineal was significantly fitter than *D. ceylonicus* on *O. monacantha* (Figure 47). Whole plant damage trials were able to show that *D. austrinus* killed *O. elata* plants faster than *D. ceylonicus* 'rioplatense' (Figure 48). There was a significant difference in the probability of survival of *O. elata,* based on the cochineal lineage it had been exposed to (Figure 48). The first *O. elata* plant infested with *D. austrinus* died by week 20, and the probability of survival had reduced to less than 1% by week 47, while it took until week 33 for the first plant infested with *D. ceylonicus* 'rioplatense' to die and week 66 for the probability of survival to be less than 1 % (Figure 48). These results clearly indicate that *D. austrinus* would be a more effective biological control agent for *O. elata* than *D. ceylonicus* 'rioplatense' and this mitigates the need for further host-specificity testing for *D. ceylonicus* 'rioplatense'.

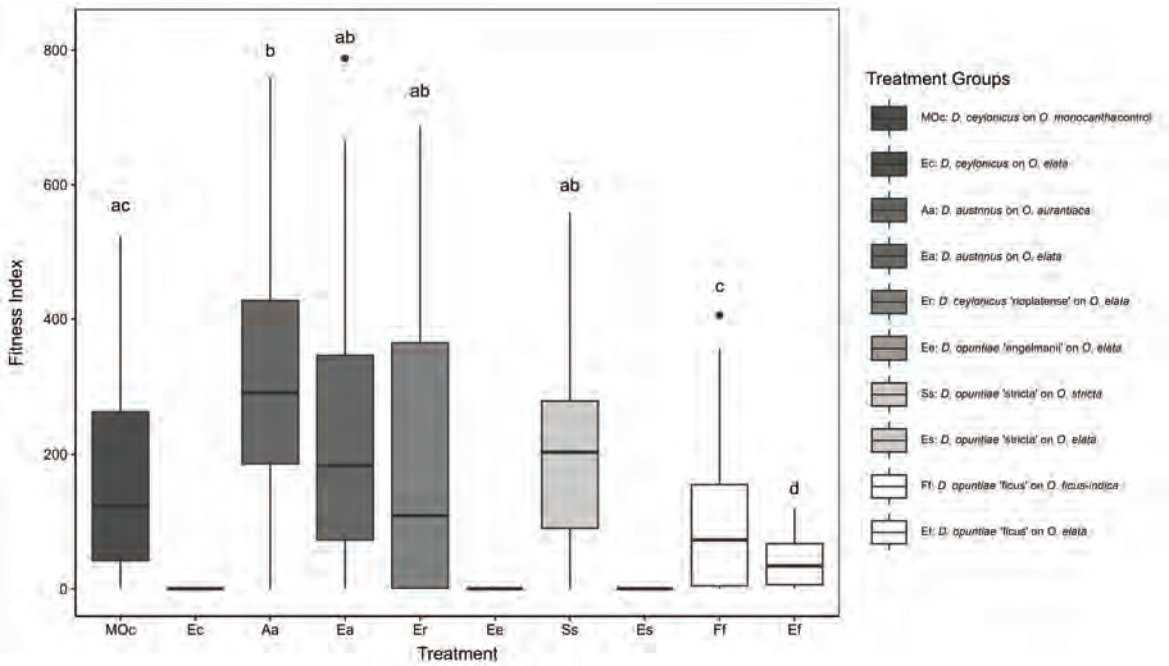

Figure 47. Fitness index calculations (survival to second instar x progeny/developmental time) for each of the cochineal and Cactaceae combinations (*D. ceylonicus* on *O. monacantha*, *D. ceylonicus* on *O. elata*, *D. austrinus* on *O. aurantiaca*, *D. austrinus* on *O. elata*, *D. ceylonicus* 'rioplatense' on *O. elata*, *D. opuntiae 'engelmannii'* on *O. elata*, *D. opuntiae* 'stricta' on *O. stricta*, *D. opuntiae* 'stricta' on *O. elata*, *D. opuntiae* 'ficus' on *O. ficus-indica* and *D. opuntiae* 'ficus' on *O. elata*). There was a significant difference ($P < 0.0001$) found between some of the treatments as indicated by the letters above each treatment; *D. ceylonicus* on *O. elata*, and *D. opuntiae 'engelmannii'* on *O. elata* were not included in the analysis because they did not establish.

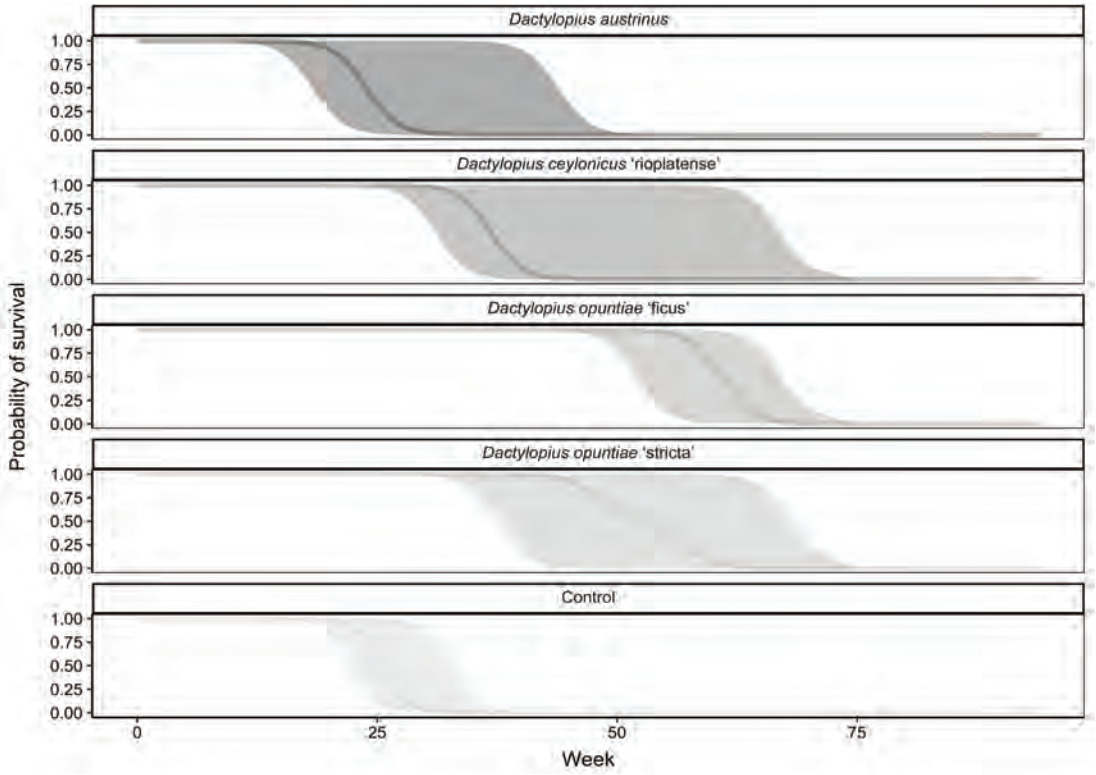

Figure 48. The mean probability of surviving *Opuntia elata* plants over the 70-week experiment, for the three species of cochineal that successfully established on *Opuntia elata* (*Dactylopius austrinus*, *Dactylopius opuntiae 'ficus'* and *Dactylopius opuntiae 'stricta'*) and the control, which is *Dactylopius ceylonicus* on *Opuntia monacantha*. The shaded ribbon represents the 95% confidence interval of the mean marginal expected value.

Torch cactus

The invasive torch cactus (*Trichocereus spachianus*) poses a significant challenge for biological control efforts in South Africa due to uncertainties surrounding its origin and taxonomy. The absence of wild *T. spachianus* populations complicates the search for host-specific biological control agents, which are typically sourced from the target plant's native range. Consequently, any biocontrol agent released against this cactus will represent a new association.

Two groups of insects were investigated as potential biocontrol agents: *Hypogeococcus* species (mealybugs) and *Dactylopius confertus* (a cochineal insect). Initial studies focused on *Hypogeococcus sp.*, an agent already deployed against other invasive cacti in South Africa. However, this species showed low suitability for torch cactus. Additional *Hypogeococcus* species and lineages from Argentina, the suspected native range of torch cactus, were subsequently evaluated. These candidates were assessed using a Suitability Index, which measured their survival, development, and reproduction on torch cactus. Despite showing some ability to establish on this host, none of the tested *Hypogeococcus* species or lineages emerged as suitable candidates.

Given the limited success with *Hypogeococcus* species, research shifted to *Dactylopius confertus*. This cochineal insect demonstrated high survival and fecundity on torch cactus and caused significant damage to the plants. *Dactylopius confertus* performed as well as, or better than *Hypogeococcus sp.* currently performs on cacti it controls in South Africa, suggesting its strong potential as a biocontrol agent. Preliminary host-specificity trials indicate that *D. confertus* is suitably host-specific, with minimal risk to indigenous or economically important plants. Further testing is required to confirm this specificity. If the new agent is proven to be host specific, an application for its release will be submitted to the relevant authorities.

Although *Hypogeococcus* were not suitably damaging to be considered as biocontrol agents, *Dactylopius confertus* is proving to be very damaging and host specific, and is therefore a very promising potential agent.

RESEARCH TEAM: Prof. Iain Paterson

STUDENT: Tamzin Griffith (PhD)

COLLABORATOR: FuEDEI

Figure 49. A dense invasion of torch cactus.

Figure 50. The large, striking white flowers of the torch cactus. Photos: Tamzin Griffith.

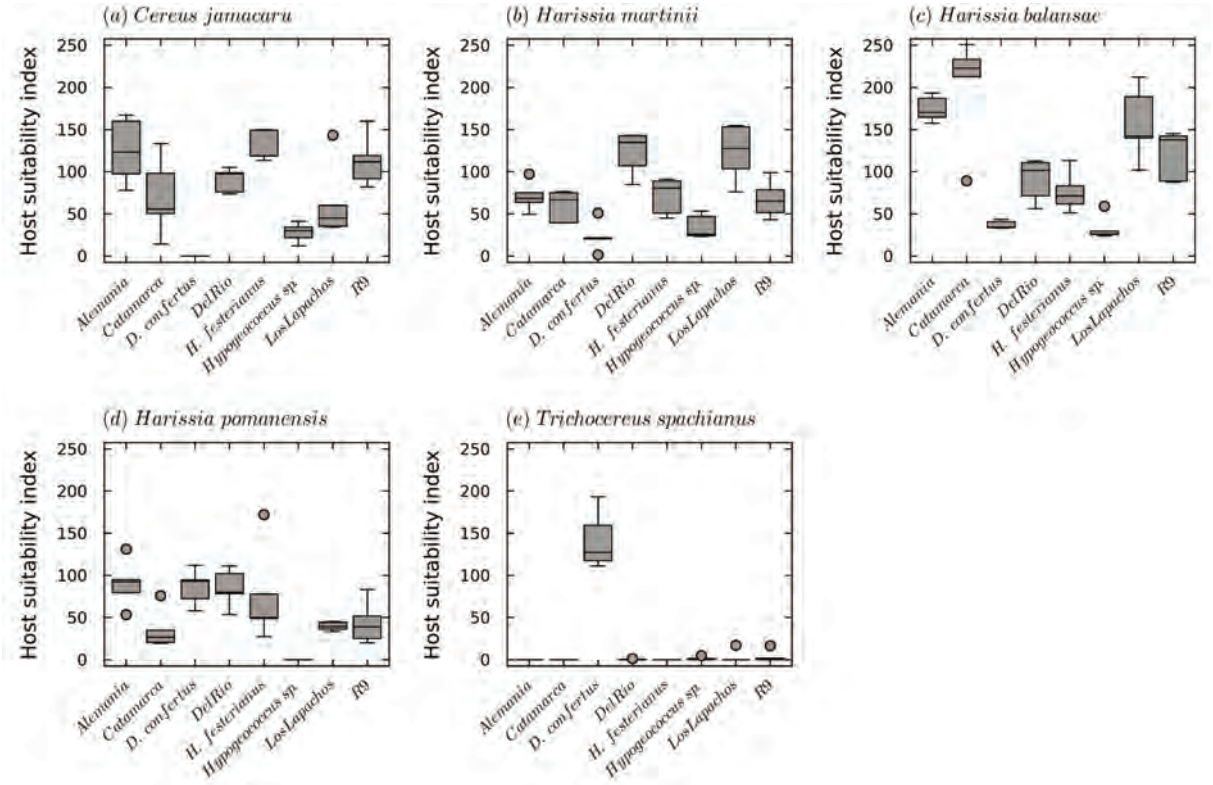

Figure 51. The suitability of cactus weeds, including the target weed (torch cactus) as hosts for all candidate agents tested. The higher the suitability index the more suitable that host is for the insect.

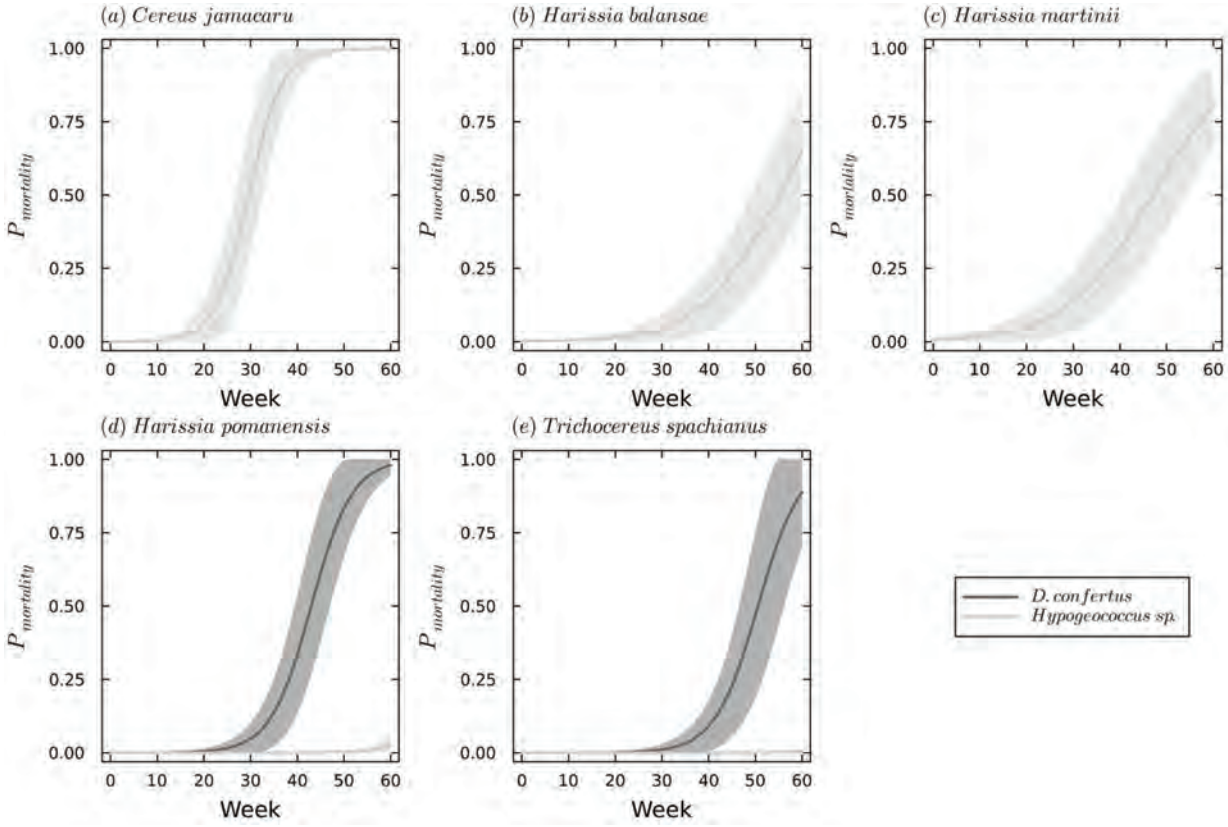

Figure 52. The probability of *Hypogeococcus* sp. and *Dactylopius confertus* causing mortality to several cactus hosts including the target weed, torch cactus.

Mass-rearing, releasing and monitoring the success of cactus biological control agents

The Kariega-based mass-rearing team had another very successful year of mass rearing biocontrol agents to release around South Africa.

Figure 53. Six of the Kariega mass-rearing team members in front of a large patch of *Cylindropuntia imbricata*. [back, from left]: Ruth Scholtz, Ronel Roman, Carmen Peters, [front] Gugulethu Mkile, Arthur Scholtz, Lubabalo Malinga.

FACILITY TEAM
Ruth Scholtz who is assisted by Byron Soetland, Carmen Peters, Gugulethu Mkile, Arthur Scholtz, Karin Goliath, Daniel Scholtz, Lubabalo Malinga and Ronel Roman.

FUNDERS
Commonlands (Netherlands)

The team reared seven biological control agents, including five lineages of cochineal (*Dactylopius austrinus*, *D. opuntiae* 'stricta', *D. opuntiae* 'ficus', *D. ceylonicus* and *D. tomentosus*) which are used to control seven cactus species, one species of *Hypogeococcus*, which is used to control three cactus species, and a beetle, *Leptinotorsa texana*, which is used as a biocontrol agent for *Solanum elaegnifolium* (Table 2). This year there was a total of 50 releases onto cactus species with 10 239 infested cladodes or *Hypogeococcus* sp. galls, as well as six releases, and a total of 748 *Leptinotarsa texana* beetles, onto *Solanum elaeagnifolium*. The rearing and release of these agents fulfil an important goal for the CBC by turning our research into practice and making a difference for land owners, farmers and indigenous wildlife throughout South Africa.

Table 2. Releases of biological control agents from the CBC Kariega mass-rearing facility from November 2023 until the end of October 2024.

WEED	AGENT	Total (November 2023 - October 2024)	
		Number of releases	Number of cladodes/galls/ beetles
Opuntia aurantiaca	*Dactylopius austrinus*	7	3125
O. stricta	*D. opuntiae 'stricta'*	13	3725
O. cespitosa	*D. opuntiae 'stricta'*	2	119
O. monacantha	*D. ceylonicus*	8	595
O. ficus-indica	*D. opuntiae 'ficus'*	6	100
O. engelmannii	*D. opuntiae 'stricta'*	0	0
Cylindropuntia imbricata	*D. tomentosus 'imbricata'*	7	1593
Cereus jamacaru	*Hypogeococcus* sp.	7	982
Harrisia martinii	*Hypogeococcus* sp.	0	0
H. pomanesis	*Hypogeococcus* sp.	0	0
Solanum elaeagnifolium	*Leptinotarsa texana*	6	748
TOTAL		**56**	**10 987**

NORTHERN TEMPERATE WEEDS

The Northern Temperate Weeds (NTW) programme aims to implement biological control in South Africa's mountain grasslands, which are vital for water security, biodiversity, and livestock farming. These ecosystems are under threat from invasive alien plants, primarily from cooler Northern Temperate regions.

The NTW programme has made significant progress, focusing on species like *Robinia pseudoacacia*, *Gleditsia triacanthos*, *Salix* x *fragilis*, *Pyracantha angustifolia*, *Cotoneaster pannosus*, and invasive *Rubus* species for biological control. In contrast, *Salix babylonica* and *Rosa rubiginosa* has been deemed unsuitable for classical weed control. The programme continues to assess other species for potential control.

Collaboration has been key, with local partnerships at the University of the Free State (both Bloemfontein and QwaQwa) and ARC-PPRI, and international partners like CABI (Switzerland), the US Forestry Science Laboratory, and Iowa State University. Additionally, NTW contributes to the global Range X project, investigating the ecological drivers of range-expanding plant species and climate change impacts. The NTW have also established the Southern African Mountains Invasive Alien Plants Working Group to foster collaboration among researchers and conservation managers to mitigate plant invasions across the region.

PROGRAMME HIGHLIGHTS 2024

- Caged, multi-choice and infield host-specificity testing for the candidate leaf galling midge *Obolodiplosis robiniae* are complete. The testing was done at CABI, Switzerland. Permission for release of the agent is now being sought.
- *Rubus* section *Cuneifolii* found to be homogenous in South Africa and a suitable candidate for biological control

Black locust

RESEARCH TEAM
Prof. Grant Martin, Dr Kim Canavan and Dr Gerald Chikowore

COLLABORATORS
CABI Switzerland (Dr Philip Weyl and Ms Lauréline Humair) and US Forest Service's Northern Research Station, West Virginia (Prof. Andrew Liebhold)

The North American Black locust, *Robinia pseudoacacia* L. (Fabaceae) is distributed in virtually every temperate and subtropical region of the world. An associated gall midge, *Obolodiplosis robiniae* Haldeman (Diptera Cecidomyiidae), has unintentionally followed the tree on its global spread and is often regarded as a pest. As the midge has not yet been recorded in South Africa, it is being considered as a biological control agent; however, despite several attempts, culturing the species under quarantine conditions has not been successful. Therefore, a three-fold method has been implemented by researchers from the CBC to demonstrate the agent's suitability as a safe biological control agent for South Africa. Firstly, the phylogenetic trees of closely related Fabaceae that share the same distribution (native and invaded range) as *R. pseudoacacia* were determined. Then information from experts in the field of galling insects, literature surveys, agricultural pest lists, social

science platforms from both the native and invaded range were used to determine if any damage (non-target attack) from the midge had ever been recorded. Experts and literature suggest that *O. robiniae* does not use any species, other than those from the *Robinoide* clade. In addition, the midge has also never been recorded on several closely related leguminous fodder and horticultural species growing in close proximity at high densities to *R. pseudoacacia*, suggesting negligible risk to South African growers of the same species.

Second, host-specificity assessments through field surveys (native and invaded range) have been conducted. These surveys are regarded as one of the best indicators of the ecological host range; however, this information is difficult to quantify and infrequently available, thus seldom used when determining the safety of a candidate biocontrol agent. Over 40 closely related species were considered growing in close proximity to *R. pseudoacacia*. No non-target attacks were recorded on any surveyed species other than the known host, again suggesting *O. robiniae* would be potentially safe for release in South Africa.

Finally, host range testing has been conducted by CABI in Europe. Black locust was introduced in Europe in the 17th century and is now naturally found in most of the continent, from southern Italy to southern Norway. Since its introduction, many of its natural enemies native to North America, including *O. robiniae* have found their way over and many cause considerable damage to the *R. pseudoacacia* and are abundant in the environment, making for a perfect setup for open field trials. The trials were completed in 2024, no galls were found on any test plants, but damage was recorded on the host *R. pseudoacacia*. In addition, large multi-choice cage tests have been conducted, seven non-targets and two controls were set up in three outdoor cages in the CABI garden. Again, no damage galling was recorded on any non-target plants, confirming the specificity of the agent. A release application for the candidate agent is currently being compiled and will be submitted in early 2025.

While conducting pre-release surveys of *R. pseudoacacia,* a strange flower colour at a potential release site alerted CBC researchers to a potential second cryptic invasion of a *Robinia* species. This species has since been identified as, *Robinia hispida* L., commonly known as the bristly locust, a native also to the south-eastern United States. The shrub has never been reported outside of cultivation in Africa. Further surveys were conducted locating additional populations near the towns of Bethlehem, Zastron and Clarens in 2024. Populations will be monitored to determine if management is required; it is expected that the candidate agent for *R. pseudoacacia, O. robiniae* should go onto the plant and might thus provide management assistance.

Honey Locust

Research team: Dr Nontembeko Dube, Dr Caswell Munyai and Prof. Grant Martin

Student: Thandeka Mahlobo

Collaborators: Dr Joyce Mokoena (UFS), Dr Frank Chidawanyika (UFS & ICIPE), Dr Chantelle Girgan and Dr Mariette Marais (ARC), and Ms Sandisiwe Zondo (KZNDARD)

Honey Locust *Gleditsia triacanthos* L (Fabaceae), is a fast-growing deciduous tree from the Central and East United States of America and has become one of the fastest-spreading alien trees in South Africa, threatening the functioning of grasslands in the country. To address this issue and aid in prioritising the tree for biological control, PhD candidate, Thandeka Mahlobo, is investigating the impacts of the tree in the grassland of the Free State Province and its phytochemical profile. To assess the impact on soil properties, nematodes, and insect communities, samples were collected across five grasslands with invaded and uninvaded patches in the Free State. These sites include two in Bloemfontein, one in Holfontein (approximately 22 km south of Kroonstad), and two in Clarens.

Preliminary findings show significant differences in insect community structures between invaded and uninvaded areas. Uninvaded areas had higher species diversity, hosted more unique and rare species, and showed greater evenness. Seasonal changes also influenced insects, with diversity and abundance peaking in summer. Secondary metabolites, that is, phenols, flavonoids and condensed tannings, were also higher in the wet season (summer). Further analyses are being performed to explore these relationships.

Soils collected under *G. triacanthos* revealed significant enrichment, with significantly higher concentrations of organic C, N, P, K, Ca and Mg. Clay percentage and exchange acidity were also significantly higher, while soil bulk density and pH were significantly lower under the tree. These results highlight the detrimental

effects of *G. triacanthos* on biodiversity, ecosystem functioning, and productivity in this vulnerable grassland. Effective management of the tree is essential to prevent further impacts.

Thermal biology studies looking into the reasons for low percentages of damaged seeds caused by the biological control agent, *M. tonkineus* (Pic, 1904) (Coleoptera: Chrysomelidae), have shown that the productivity and survival of *M. tonkineus* are affected by temperature, especially fluctuating temperature

Willows

RESEARCH TEAM
Prof. Grant Martin and Prof. Sandy Steenhuisen (UFS-ARU),

STUDENT
Tapiwanashe Mashamba (MSc)

The Salix species, commonly referred to as Willows, are a diverse group of dioecious trees and shrubs that originate from the Northern Temperate regions. However, these species have become invasive in many parts of the world, including the grassland biome of South Africa. Willows can have significant effects on the environment, including altering the biodiversity of a region, disrupting ecosystems, and causing economic losses. The two most prominent invasive species in South Africa's grassland are *Salix babylonica*, known as the weeping willow, and *Salix fragilis*, the crack willow. These two species remain abundant and are currently classified under the CARA regulations.

Tapiwanashe Mashamba completed his MSc this year with a reassessment of the population demographics of these two willow species in the Free State and Eastern Cape provinces. The objective is to determine if biological control should be pursued. Tapiwa was able to show through road survey, historical satellite images and Google Street view that there has been limited recruitment of *S. babylonica* in recent decades, suggesting a potential decline in its invasive potential with almost 80% of the population consisting of adult or dying trees. In contrast, *S. fragilis* populations display a continuous expansion with healthy recruitment, with 44% of the trees recorded as seedlings, young trees, or mature trees. His research also investigated interactions between invasive willows in South Africa and invertebrate communities. Surveys at selected sites document the presence of 21 families, with 14 species associated with both willow species. Some of these potentially have a significant influence on the plants. Another finding was the presence of the crown galls on 28% of all *S. babylonica* population surveyed; this gall is likely to be contributing to the reduced vigour of *S. babylonica*.

Invasive Rosaceae

RESEARCH TEAM
Prof. Grant Martin, Prof. Sandy-Lynn Steenhuisen (UFS-ARU) and Dr Stephanie Payne (UFS Dept. Plant Sciences)

STUDENT
Karabo Moloi (PhD)

Invasive Rosaceae species are increasingly becoming dominant and problematic in the grassland biome of South Africa. Over the past six years, the Plant Sciences Department and the Afromontane Research Unit at the University of the Free State, in collaboration with the CBC, have been conducting a series of plant reproductive ecology experiments on several problematic invasive Rosaceae species. These species produce a large number of fruits and seeds, contributing to their rapid spread and dominance in the environment. High soil seed bank numbers and seed viability are all factors that facilitate their invasion. Furthermore, owing to the fleshy nature of the fruits, these seeds are dispersed by birds and mammals into novel and inaccessible environments.

Managing these invasive Rosaceae species is a complex task. However, through a meticulous analysis of each species, certain stages of the plant life cycle can be identified for targeted management. For instance, the seeds of *Pyracantha angustifolia* have a short lifespan in the soil seed bank. In contrast, the seed dispersal of *Cotoneaster pannosus* is not facilitated by birds. Therefore, despite their high productivity, different solutions can be explored to control or mitigate the spread of these species. At this stage, biological control is the only feasible large-scale control option for these species. The findings from this research will help guide their management.

Rosaceae complex

PhD candidate, Karabo Moloi, is currently exploring the transformative impacts of invasive Rosaceae species on grassland ecosystems, as well as the potential for ecosystem resilience. The research is based on the hypothesis that the introduction of winter-fruiting invasive Rosaceae species has created changes, such as additional resources and shelter, that were previously absent within the ecosystem. These benefits are particularly attractive to native insects, rodents, birds, and mammals, leading to significant changes in the community composition of species that benefit from the additional resources during harsh winters of the grassland and protection from predators.

The Rosaceae species selected for the study include *Cotoneaster pannosus, Rosa rubiginosa, Pyracantha angustifolia*, and the native species *Leucosidea sericea*. The study aims to document and compare the species traits that facilitate their invasion, determine whether ecosystem biotic resistance plays a role in preventing these species from completely overwhelming the invaded area and invading new regions, and investigate the role of the selected invasive Rosaceae species as ecosystem engineers.

In addition, the study will also determine the distribution of the selected Rosaceae species in South Africa, and their potential spread with climate change. This research is crucial as it can provide valuable insights into the effects of invasive species on grassland ecosystems and the potential for ecosystem resilience. Preliminary results indicate that the sites invaded by these invasive Rosaceae shrubs have higher species diversity and abundance of rodents and birds. Additionally, with predicted global warming, bioclimatic modelling indicates that the number of suitable habitats for these species to thrive will decrease. The findings of this study could inform strategies for managing invasive species and conserving grassland ecosystems.

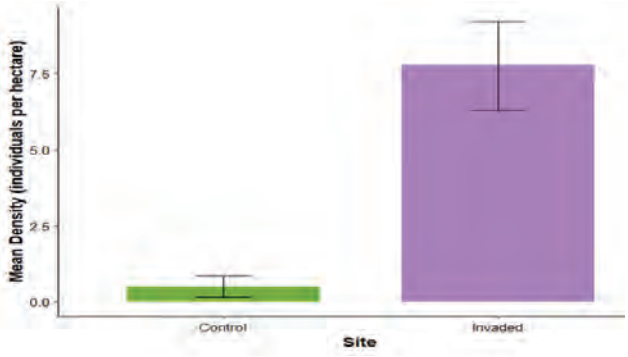

Figure 54. Comparison of rodent density between open grassland (control) and sites invaded by invasive Rosaceae shrubs in grasslands of eastern Free State.

Orange firethorn

Pyracantha angustifolia is a medium-sized, evergreen shrub, native to north-eastern China, which is increasingly becoming invasive in warm temperate climates worldwide. The species' ability to survive in areas affected by frost and its attractive orange to red berries have contributed to its horticultural success. Once planted, the shrubs' berries are eaten and distributed by birds and mammals. The species has been identified as one of the most damaging and fastest spreading species in the grasslands of South Africa and is therefore a candidate for biological control.

This year Lehlohonolo Adams completed his PhD on the species. Lehlohonolo investigated the integration of the species into rural communities. Interviews revealed that landowners tried different methods including chemical and mechanical applications to control the species, but none was successful, and the species is becoming more invasive. Although the communities use the species for various purposes, it is not of subsistence use thus less conflict is expected should the species be controlled.

RESEARCH TEAM
Prof. Grant Martin, Prof. Sandy Steenhuisen (UFS-ARU), Prof. Colleen Downes (UKZN) and Dr Lehlohonolo Adams

Lehlohonolo has also been investigating the importance of larger mammals in the long-distance dispersal of the seeds, showing species such as baboons and eland may be able to transport the seeds over long distances, in addition to increasing their viability. Finally, by using road-side surveys and Google Street view of the grassland biome, Lehlohonolo was able to show that the species is the fastest spreading among fleshy-fruited invasive alien plants in the grassland biome. A biological control programme for this species was initiated through a collaboration with Prof. Huang Wei from the Chinese Academy of Sciences, China. The project is currently looking at funding opportunities to continue this research.

Rosa spp

Despite the economic significance of *Rosa rubiginosa*, which has led to the discontinuation of biological control programmes, ongoing research is being conducted to investigate whether the species is driving bush encroachment into the grassland biome and to study the seed ecology of the species. This year Patricia Masole completed her MSc on the species. Patricia was able to show that while the seeds of the invading *R. rubiginosa* population exhibit low germination percentages, they remain viable in the soil for over two years. In addition to the long seed bank life, the plant produces many seeds, with an average of 480 ± 57 fruits per shrub, and an average of 18 seeds per fruit per annum. Patricia was also able to show that the associated introduced seed predator *Megastigmus aculeatus* (rose seed chalcid) probably does not have a controlling influence over the species at this stage, with only about 1% of seeds predated. Patricia also confirmed that *R. rubiginosa* acts as a nurse plant and facilitates the recruitment of invasive woody plant species into the grasslands. During her studies, Patricia noted some morphological variation within *Rosa* populations that probably warranted clarification.

RESEARCH TEAM
Prof. Grant Martin, Prof. Sandy Steenhuisen (UFS-ARU) and Dr Stephanie Payne (UFS Dept. Plant Science)

STUDENTS
Patricia Masole (MSc), Zinhle Sithole (Hons.)

This year Zinhle Sithole has started her MSc to determine what is driving the variation in Rosa plants. Zinhle has thus far conducted extensive studies into the morphology of the different-looking species, noting differences in thorn shape, flower colour and fruit colour, and the number of trichomes on the fruits. To further elucidate the differences, Zinhle has collected samples for genetic analysis as well as leaves which are being inspected under an electron microscope to determine differences in leaf trichome number and shape. Finally, Zinhle has been collecting fruits from the different-looking plants to determine if the seed predator *Megastigmus aculeatus* performs equally on all 'varieties' of Rosa. At this stage it is suspected that South Africa has a cryptic invasion of a second Rose species which has gone unidentified.

Rubus spp.

Research into the biological control options for *Rubus* species in South Africa has been *ad hoc* over the last six years as it has not been directly funded. However, due to the recognised significant impact of the species, research towards developing a biological control programme has been conducted by the Centre for Biological Control, in collaboration with the Agricultural Research Council – Plant Health and Protection (ARC-PHP), Cedara. Fortuitously, while research in biological control has been conducted, there has also been significant progress made towards untangling the complexities of the *Rubus* genus in South Africa. This has been facilitated by researchers from South African National Biodiversity Institute (SANBI) and the Centre of the Region Haná for Biotechnological and Agricultural Research, Crop Research Institute, Czech Republic.

Several taxa of alien *Rubus* (Rosaceae) are invasive in South Africa. Chief among these are taxa that have been referred to in the past as *Rubus cuneifolius* (American bramble). Collections made through this project have clarified that this historical *Rubus cuneifolius* can be divided into two separate sections:

RESEARCH TEAM
Prof. Grant Martin, Dr Kim Canavan and Dr Costas Zachariades (ARC-PHP)

Rubus section *Cuneifolii* and *Rubus* section *Arguti*. In addition, extensive sampling of populations of these two new sections across much of the invaded range has genetically confirmed which of the two new sections are having the largest impact and where they are distributed in South Africa. The survey showed that the invasive populations are dominated by *Rubus* section *Cuneifolii* rather than by *Rubus* section *Arguti;* however, both can be regarded as abundant and damaging. There appears to be no spatial or elevational separation of the two sections as was previously thought. Additionally, these surveys identified morphological characteristics that allow *Rubus* section *Cuneifolii* to be distinguished from *Rubus* section *Arguti* by having more upright stems than the curving stems of *Rubus* section *Arguti*.

A molecular study using microsatellites was used to confirm the genetic identity of sampled species, in

addition to highlighting the genetic diversity of these two taxa in South Africa. The study showed that samples regarded as *Rubus* section *Cuneifolii* are all homogeneous –- a single genotype – while plants identified as *Rubus* section *Arguti* have three repeated genotypes in South Africa plus two unique genotypes. This provides further support that *Rubus* section *Cuneifolii* remains a good candidate for biological control if a close genetic match can be located in North America. The project is currently working with collaborators to obtain genetic material from Herbaria in the USA to find closely related parent plants in the USA and to find collaborators who will accept South African trap plants that can be planted at selected sites in North America in order to attract and harvest natural enemies as candidates for importation into South African quarantine.

The Range X project

The high elevation regions of South Africa have unique, specialised, and endemic plant species as the environment is harsh. However, predicted global climate change may open this unique niche to both native and invasive 'lowland' plants which will have a major impact on ecology, livelihoods, endemic alpine species, and water production in these high areas. To inform and guide policy, as well as management within these regions, it is important to understand the process of species migrating upwards as a result of climate change. The Afromontane Research Unit (ARU) has partnered with the European Union's Horizon 2020 initiative called 'The Range X project' which aims to investigate mechanisms underlying the success of and impacts on biodiversity and ecosystem functioning of range-expanding species under climate change, across the globe. The ARU component of Range X is funded by the Department of Science and Innovation through BiodivERsA. The CBC's Northern Temperate Weeds programme is collaborating with ARU in this initiative, investigating how invasive Rosacea species might perform at different elevations under changed climate conditions. A full-factorial warming experiment is underway using open top chambers (OTCs) placed on the top of Sentinel Peak (3100 m) and comparing them to OTCs positioned at lower altitudes near the Witsieshoek (2180 m). The OTCs are widely used to mimic global warming as they are very effective in elevating ambient temperatures by 1-2 °C. The CBC aims to determine how the invasive species and the native biodiversity respond to standard management practices at different altitudes by using matched plot designs and clearing large areas of woody invasives over an increasing altitude gradient. ARU

RESEARCH TEAM
Prof. Grant Martin, Dr Gerald Chikowore, Prof. Sandy Steenhuisen (UFS-ARU), Prof. Vincent Ralph Clark (UFS-ARU), Dr Stephanie Payne (UFS-ARU) and Dr Ona Gwate (UFS-ARU)

STUDENT
Lesego Malekana (MSc)

COLLABORATOR
Jake Alexander (ETH Zurich, Zürich)

Post-doctoral candidate, Ona Gwate, has now completed two years of sampling with some very interesting results, one of which shows that the entire altitudinal range of the Drakensberg Mountain system is suitable for the establishment of a number of invasive Rosaceae.

This year Lesego Malekana completed his MSc, with a study that showed that invasive Rosaceae species had a significant, negative impact on native biodiversity in the Maloti-Drakensberg region. These invasive species, including *Cotoneaster pannosus*, *Pyracantha angustifolia*, and *Rosa rubiginosa*, led to a reduction in native grass diversity and cover across different elevations. He further showed alterations in soil properties at higher elevations due to the invasion. Following clearance efforts, notable differences in temperature and light intensity were observed between cleared and uncleared treatments, facilitating vegetation recovery. While native vegetation did recover, along with increased species diversity and abundance, this process was slower at higher elevations. Unintended secondary invasion by resident alien species occurred during clearance attempts.

Toadflax

RESEARCH TEAM
Dr Kim Canavan, Prof. Grant Martin, Dr Gerald Chikowore, Prof. Sandy-Lynn Steenhuisen (UFS-ARU) and Thembelihle Mbele (MSc student UFS Dept. Plant Sciences)

STUDENT
Sanele Mfusi (Hons)

Two species of toadflax have established in South Africa: *Linaria dalmatica* (L.) Mill. and *Linaria vulgaris* Mill and they are listed as category 1b invaders under the National Environmental: Biodiversity Act (NEMBA). These toadflax species were introduced into the country as ornamentals. There has been almost no research on the plants, and records indicate that they were restricted to only a few localities in South Africa. This study performed risk analysis assessments on the two species to ascertain what records are currently available, research gaps and the potential risk they pose. Based on the number of occurrence records for both species, it is evident that their populations are increasing and they are likely to be more widespread than realised. Toadflax present considerable environmental and economic risks, including toxicity to livestock and displacement of native species. There are currently no management initiatives in place to control the spread of toadflax, and the potential for implementing biological control needs to be explored. Biological control has been implemented in Canada and the US using several biocontrol agents and has achieved effective control of *Linaria* spp. across much of their invasive range. This study has highlighted major knowledge gaps on the invasive toadflax in South Africa and has shown the potential to implement biological control strategies to begin to curb their spread.

Figure 55. *Linaria dalmatica* growing in the Free State, South Africa. Photo: Kim Canavan.

Figure 56. *Linaria dalmatica* growing in disturbed land in Ficksburg, Free State. Photo: Kim Canavan.

INVASIVE TREES

The Invasive Trees Programme team is made up of Emeritus Associate Professor John Hoffmann, Fiona Impson and Catharina Kleinjan. They are based at the University of Cape Town in the Department of Biological Sciences and have been part of the CBC Consortium since 2017. This team has many years of experience in the field of biological control of invasive trees and has developed strong collaborations with several international institutions.

The Invasive Trees Programme continues its focus on the biological control of several Australian *Acacia* (wattle) species, as well as *Neltuma* (prosopis, mesquite) species originating from both South and North America. Australian acacias and prosopis remain particularly important and destructive invaders across large parts of South Africa. Both groups of trees share common uses in being beneficial agroforestry trees, providing timber, fuel, fodder, and shade, but where they have become invasive, their negative impacts on biodiversity and water resources outweigh any benefits, and management and control of further spread of these species is necessary.

The commercial utilisation of several *Acacia* species has largely restricted biological control to the use of agents that have no impact on the vegetative growth of these trees (i.e., agents that attack the buds, flowers or seeds). Despite this constraint several agents are now well established and curbing the invasiveness of the acacias, and efforts are underway to introduce additional, different species of agents.

Whilst there has been some success with biological control of prosopis to date using two seed-feeding beetles, levels of control have not been enough to alleviate the problem. Engagement with stakeholders in the farming community created an incentive to expand the biological control programme to include agents that are destructive on other parts of the trees. Permission for release of two additional agent species has been granted and releases of both commenced in the spring of 2021.

Despite continued funding challenges during 2024, which have severely limited the field activities of the group, progress has been made on both these invasive tree projects. Collaboration with colleagues at the Instituto Politécnico de Coimbra in Portugal, Tel Aviv University in Israel, FuEDEI in Argentina and Manaaki Whenua Landcare Research in New Zealand has continued.

Australian Acacias

A 20-year study looking at the impacts of fire, clearing and biological control on seed banks and densities of *Acacia cyclops* was published early in 2024.

During May, Prof. Grant Martin collected approx. 300 *Melanterius maculatus* weevils from *Acacia dealbata* and 300 *M. acaciae* from *A. melanoxylon* in the Eastern Cape which were delivered to colleagues in Portugal to assist with the further development of their biological control programme.

A small sample of approximately 60 mature galls of the flower galling midge, *Dasineura pilifera* which had been collected in Stellenbosch from *Acacia baileyana* in October 2023 was released at two sites during May 2024: one on *A. dealbata* close to Joubertina (Eastern Cape) and the other on *A. baileyana* near Somerset

RESEARCH TEAM
Emeritus Associate Prof. John Hoffmann, Fiona Impson and Catharina Kleinjan

COLLABORATORS
Instituto Politecnico de Coimbra and Centre for Functional Ecology, University of Coimbra, Portugal; Manaaki Whenua - Landcare Research New Zealand

West (Western Cape). During a trip to Mpumalanga in October 2024 Fiona Impson confirmed establishment of the midge at two sites where releases had been carried out in 2023 (one on *A. decurrens* and one on *A. dealbata*). At both these sites there was evidence of old galls from the 2023 release and new (second generation) galls which gives promise for the persistence of this species in summer rainfall regions.

Following the first releases (3257 females) of the bud galling wasp, *Perilampella hecataeus,* in December 2023 at nine sites (eight on *A. baileyana* and one on *A. dealbata*) establishment was confirmed at five of the sites (four in the Western Cape and one in Mpumalanga) during September/October 2024. At one of the sites in Stellenbosch, the level of galling was substantial, and allowed for a collection of 170 galls which were couriered to the Free State. Galls were released at a site near Clarens, marking the first releases in the grassland biome and female *P. hecataeus* wasps, which had emerged during transit, were observed searching and probing on the young shoots of the *A. dealbata* trees they had been released onto.

Figure 57. The first *Perilampella hecataeus's* galls on *Acacia baileyana* observed in South Africa. Photo: Fiona Impson.

The collaborative project on *Acacia longifolia* with Manaaki Whenua - Landcare Research New Zealand continued in 2024. Two shipments of the bud-galling wasp, *Trichilogaster acaciaelongifoliae*, from South Africa in 2022 and 2023, had resulted in several releases of the wasp in New Zealand and establishment at some sites. During November 2024, Dr Angela Bownes visited Stellenbosch from New Zealand to collect a further consignment of galls and to witness first-hand the impacts of *T. acaciaelongifoliae* on *A. longifolia* in South Africa. Approximately 20 kg of galls were collected and taken back to New Zealand. Following previous experiences with delays in the release process, and consequently few females being available for release, the process had been streamlined to allow disease testing and final release permission to take place quickly (within eight working days); this should allow for good emergence (and releases) during December this year.

Figure 58. Angela Bownes collecting *Trichilogaster acaciaelongifoliae* galls for export to New Zealand. Photo: Fiona Impson.

During 2024, the invasive trees team hosted several international visitors who were interested in learning more about the *Acacia* biocontrol programme in South Africa. This included Dr Silvia Ziller, from the Horus Institute for Conservation & Development in Brazil, and Associate Prof. Carey Minteer (University of Florida), Dr Melissa Smith (USDA-APHIS Invasive Plant Research Lab., Fort Lauderdale), and two graduate students, Megan Reid and Madison Self. In Cape Town, John Hoffmann gave a lecture on *Acacia* biological control to a delegation from the Middle East.

Pines

The invasion of the Cape Floristic Region (CFR) in South Africa by wilding pines poses significant threats to native biodiversity, water resources, and local communities, particularly due to recurrent fires. Current management strategies primarily involve mechanical removal, a costly and logistically challenging method given the steep, rugged landscapes in which these invasions often occur. Furthermore, mechanical control alone has proven unsustainable owing to frequent re-invasion. Biological control offers a more sustainable, cost-effective alternative for managing invasive alien plants (IAPs) and can provide a long-term solution to wilding pine invasion in South Africa.

Figure 59. Damage on pine cones consistent with *Pissodes validirostris* feeding.

The Centre for Biological Control (CBC) at Rhodes University, in collaboration with various institutions, including The Nature Conservancy (TNC), the Forestry, Agricultural and Biotechnology Institute (FABI) at the University of Pretoria, Coimbra University in Portugal, the Institut National de la Recherche Agronomique (INRA) in France, and Forestry South Africa, is exploring the biological control of pine seeds in the CFR. The focus is on the cone weevil, *Pissodes validirostris*, which targets three pine species, *Pinus pinaster*, *P. halepensis*, and *P. pinea*, reducing their reproductive potential while allowing continued commercial use of the trees. Although early research was halted in 2009 due to concerns over the weevil's potential role in spreading pine pitch canker (*Fusarium circinatum*), new evidence suggests minimal transmission risk owing to limited feeding of the adult weevils on leader shoots under field conditions, coupled with their low dispersal capacity.

RESEARCH TEAM
Dr Kim Canavan, Prof. Grant Martin, Dr Gerald Chikowore and Prof. Martin Hill

STUDENT
Nkhoye Zondo

COLLABORATORS
Prof. Brett Hurley (FABI), Prof. Bernard Slippers (FABI), Prof. Irene Barnes (FABI) Prof. Heila Marchante (University of Coimbra), Dr Elizabete Marchante (University of Coimbra), Louise Stafford (TNC), Prof. John Hoffmann (UCT)

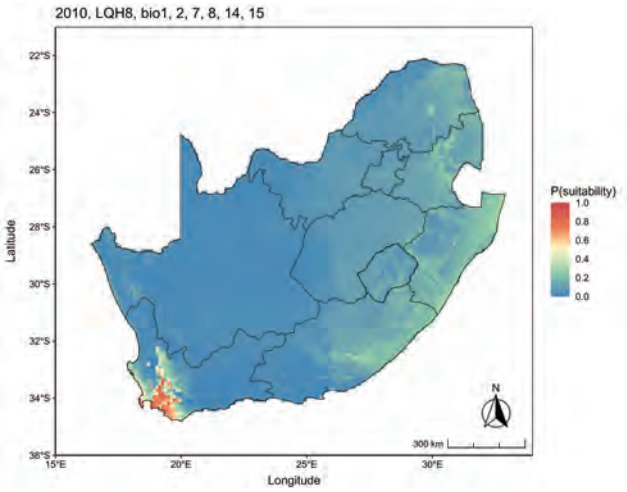

Figure 60. The potential distribution from all occurrence records of *Pissodes validirostris* in South Africa under current climatic conditions.

Current research is focussed on determining the potential geographic range of *P. validirostris* in South Africa; assessing how host plant volatiles influence the weevil's oviposition site selection; and resolving the taxonomy of the Iberian clade of *P. validirostris*. Species distribution models indicate that the Iberian biotype will likely remain confined to the CFR, where climate conditions mirror its native habitat. An integrative taxonomic approach has identified three phylogeographic clades of

P. validirostris: the Iberian Peninsula lineage, the Central European lineage, and the Northern and Eastern European lineage. Notably, the Iberian clade's adults are significantly larger than those of other clades. Ongoing weevil collections aim to establish a culture for chemical ecology studies and mass-rearing trials, advancing the development of this biological control strategy.

Neltuma

RESEARCH TEAM
Emeritus Associate Prof. John Hoffmann (UCT), Fiona Impson (UCT), Catharina Kleinjan (UCT), Philip Ivey (RU) and Blair Cowie (Wits)

COLLABORATORS
Dr Fernando McKay, FuEDEI, Argentina; Lulu Madire, ARC-PHP; Elmarie Hoft, Hennie du Plessis and team at Benede-Oranje Association of and for Persons with Disabilities (Upington); Graham Harding of Invader Plant Specialists; Eben Anthonissen of AgriNoordKaap; Philip van Staden of Slowburn Enterprises, Dirk Oosthuizen of Natural Engineering Solutions and numerous other stakeholders in the Northern Cape

moth, *Agnippe sp.*, and a seed-feeding weevil, *Coelocephalapion gandolfoi*), were released against prosopis to supplement the activities of the seed-feeding beetles already present in South Africa. Subsequent to the departure of Mr Fritz Heystek and Ms Yogi Kistensamy, the *Agnippe* programme is managed by Dr Lulu Madeira (ARC-PHP, Roodeplaat, RSA) with members of the CBC consortium assisting with distribution and monitoring of sites on an opportunistic basis during travel to the Northern Cape.

Funding constraints have precluded import of additional consignments of *C. gandolfoi* from Argentina; earlier evaluations revealed the persistence of *C. gandolfoi* at two of the original release sites in 2022 and at one site in 2023, with evaluation for 2024 currently pending. These evaluations revealed that counter to previous reports, *Algarobius prosopis* does utilize immature prosopis pods in South Africa, as it reported to do in America. The impacts are likely minimal.

The year 2024 was a good year for the overall management of mesquite in the Northern Cape, South Africa, given the funding constraints. In January 2024, Dr Lulu Madire (ARC-PHP), Dr Blair Cowie (Wits) and Prof. Martin Hill (CBC) travelled to Upington with hundreds of leaf ties containing *Agnippe omphalopa* insects. The insects were delivered into the care of the team at the biological control mass-rearing facility managed by the Association of and for Persons with Disabilities, Benede-Oranje, in Upington. Thanks to the tireless efforts of Elmarie Hoft and Hennie le Roux had secured three-phase electricity for the facility which can now provide controlled environmental conditions for both plants and insects. Engie Africa (operators of Xina Solar 1) had provided the financial support for the installation of the three-phase electricity. The three researchers presented the staff with polystyrene cooler boxes filled with leaf ties. Lulu Madire demonstrated to the team how to transfer the leaf ties onto the mesquite plants in the cages. After many months of uncertainty due to the cut in government funding, we were able to progress to the next stage of the *Agnippe omphalopa* mass-rearing project.

The three researchers then travelled to two of the field release sites to investigate whether there was evidence of the moth in the field, and to release additional moths at each site. The trio visited both the Witsand and the Kenhardt-Rugseer sites where they observed evidence of establishment of the moths as demonstrated by the presence of leaf ties near where Fritz Heystek had released the moths.

During this time, Graham Harding (Invader Plant Specialists), Philip van Staden (Slowburn Enterprises), Dirk Oosthuizen (Natural Engineering Solutions) and Philip Ivey visited a commercial irrigation farm outside of Prieska to discuss the most appropriate plans for management of mesquite and use of the biomass from this and other farming operations. Graham Harding and Philip van Staden prepared plans and submitted ideas to the farm managers who still need to make decisions about investment in these activities. They also visited the community of Marydale between Prieska and Groblershoop to discuss and plan for management of mesquite in the communally managed areas. Again, they drew up plans, but lack of funds means that the community cannot implement these.

Figure 61. Thabelo Khoele and Dr Lulu Madire placing *Agnippe omphalopa* leaf ties onto mesquite plants at the biological control mass-rearing facility in Upington. Photo: Blair Cowie.

In April 2024, Catharina Kleinjan accompanied Philip Ivey (CBC) to the Northern Cape in response to reports from a local farmer that prosopis trees were exhibiting symptoms possibly indicative of widespread and rapid dispersal of *Agnippe*. This proved not to be the case, although prosopis was clearly displaying symptoms of stress. No clear cause for these symptoms could be established and follow-up monitoring is required.

Thanks to the Centre for Biological Control's work on mesquite, colleagues from Sol Plaatje University in Kimberley were keen to work with the CBC to address the threat of this invasive plant to human livelihoods and biodiversity. This led to organising and co-hosting the National Symposium on Biological Invasions at Sol Plaatje University, 9–12 September 2024.

At this symposium, four of the presentations gave insights into the management of mesquite.

- Carien Kleinjan, UCT: 'Promising gall-forming insects from Argentina for management of *Neltuma* (previously Prosopis section *Algarobia*) in South Africa.'
- Alan Wood, ARC-PHP: 'The development of potential of bark and wood canker pathogens as a biological control treatment against invasive Prosopis in South Africa.'
- David Kinsler, RU CBC: 'Can remote sensing effectively monitor Prosopis (*Neltuma*) invasions in southern Africa? Broader implications for monitoring biological invasions.'
- Mohamed Abd Elbasit, Department of Physical and Earth Sciences, Faculty of Natural and Applied Sciences, Sol Plaatje University: 'Mesquite survival strategies in arid environments.'

Another consequence of the work on mesquite was an invitation from Professor Brian van Wilgen of the University of Stellenbosch who invited the CBC to prepare and host a summer school for a delegation from the Kingdom of Saudi Arabia. The focus of the visit was, "Invasive alien plant management with a focus on biological control". Philip Ivey drew together a range of lecturers on invasive plant management and the CBC hosted the delegates for two weeks. A field trip to the Northern Cape showed the delegation mesquite management in the field and the mass-rearing facility in Upington.

The collaboration with Sol Plaatje University on mesquite management has continued, with David Kinsler and Philip Ivey travelling with Mohamed Elbasit to the site of a Global Environment Facility funded project in the Dawid Kruiper District Municipality. This project links closely with a project that the JRS Biodiversity Foundation is supporting in which the CBC is working with colleagues in Botswana, Namibia and South Africa to manage the impact and spread of mesquite. David Kinsler and Philip Ivey have gathered data that will help predict the amount of biomass that is present in invasive stands of mesquite, allowing us to plan the management of mesquite at different sites.

Figure 62. Gledvin Pearson, Siboniso Thela, and Dave Kinsler with a mesquite in Kgalagadi Trans-frontier Park.

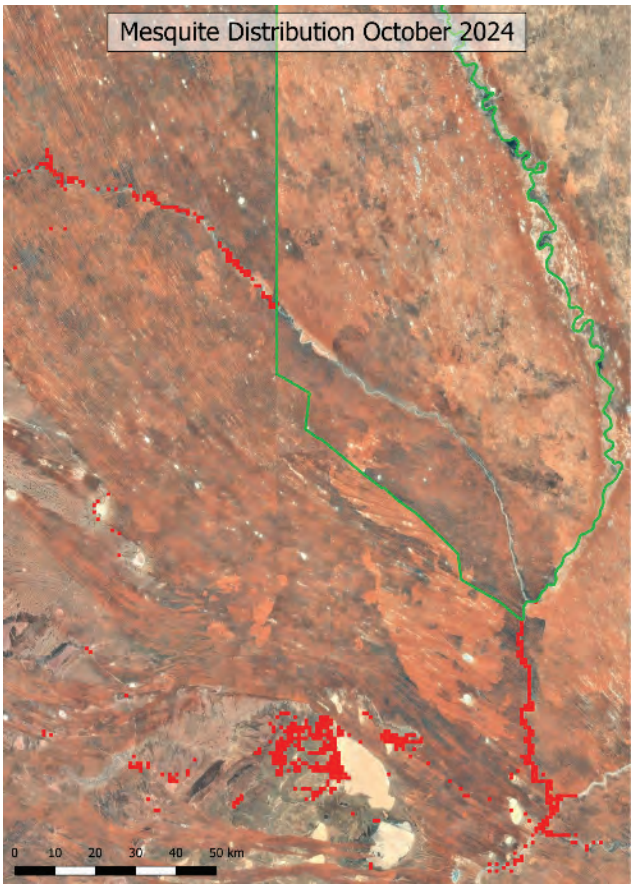

Figure 63. First draft of map plotting distribution of mesquite in the north-west section of Dawid Kruiper District Municipality and Namibia on the boundaries of the Kgalagadi Transfrontier Park.

In early December 2024, Lulu Madire released *Agnippe omphalopa* leaf ties at both the Bloemhof and Modderrivier sites to enhance the chances of establishing and spreading of the agent. *Agnippe omphalopa* was still present at Modderrivier, but there was not much activity at Bloemhof. The moth was also sent to the mass-rearing facility in Upington to enhance the culture and release it in the nearby infestation of mesquite.

The year ended on a high as a private benefactor offered to support the full running costs of the biological control insect-rearing facility at the Benede Oranje Association of and for Persons with Disabilities in Upington for five years. Options for mesquite management in the Northern Cape are looking good.

BUGWEED

RESEARCH TEAM (WITS)
Dr Nic Venter and Dr Blair Cowie

STUDENT
Mr Yaron Keizan (MSc, Wits)

COLLABORATORS
Prof. Terry Olckers (UKZN), Dr Angela Bownes and Dr Simon Fowler (LandCare Research New Zealand)

Bugweed (*Solanum mauritianum*), an invasive plant species native to subtropical South America, has spread extensively across South Africa. Two insect biological control agents, the lace bug (*Gargaphia decoris*) and the flower-feeding weevil (*Anthonomus santacruzi*), were released in 1999 and 2008, respectively. While both agents have established populations capable of inflicting damage, their effectiveness is largely confined to warmer, low-altitude areas. High-altitude regions in South Africa, which lie above 1,000 metres and experience cold winters, remain significantly affected by bugweed. However, owing to climatic incompatibility, these agents have not established populations in these cooler regions.

To address this gap, a new biological control agent, the flower-feeding weevil, *Anthonomus morticinus*, was collected in 2020 from temperate areas of Uruguay. These regions share similar climatic conditions with South Africa's high-altitude areas where bugweed thrives. Laboratory thermal assessments suggest that *A. morticinus* is better adapted to low temperatures than *A. santacruzi*. However, humidity trials reveal that *A. morticinus* has a lower tolerance for humidity than *A. santacruzi*. Despite this limitation, its ability to endure colder temperatures is promising.

Host-range testing of *A. morticinus* is ongoing, with encouraging results. Preliminary findings suggest that its host range on commercially grown Solanaceae species is similar to or narrower than that of *A. santacruzi*. Since many Solanaceae species are vital crops for human consumption, it is crucial to ensure that bugweed biocontrol agents do not negatively impact these plants. Testing is also being conducted to assess the host range of *A. morticinus* on South Africa's native Solanaceae species, and early results are promising.

In December 2023, two additional candidate agents, a flea beetle (*Epitrix* sp.) and a leaf-tying moth (*Gelechiid* sp.) were collected in Uruguay and imported into Wits Quarantine. The decision to import these agents was based upon observations made in their native range, where they were abundant, damaging, and appeared specific to bugweed. Unfortunately, host-range testing indicated non-target effects on potato (*Solanum tuberosum*) and further testing was suspended.

In collaboration with Manaaki Whenua Landcare Research in New Zealand, Wits University is testing the host range of *A. morticinus* on two Solanaceae species native to New Zealand. These trials are currently being conducted at the Wits Quarantine Facility.

Figure 64. Host range testing of *Anthonomus morticinus* on indigenous *Solanums* species at the Wits Quarantine Facility, Johannesburg, August 2024. Photo: Nic Venter.

STICKY NIGHTSHADE

The project is a risk analysis of introducing *Gratiana spadicea* (Klug, 1829) (Coleoptera: Chrysomelidae: Cassidinae) into Australia as a biocontrol agent for *Solanum sisymbriifolium* Lamarck (Solanaceae). This project arose from a request from the NSW Department of Primary Industries for Rhodes University, Centre for Biological Control to quantify the risk that the leaf-feeding beetle, *Gratiana spadicea,* may pose to 20 native Australian *Solanum* species during host-range testing in South African quarantine.

The shrub *Solanum sisymbriifolium*, commonly known as wild tomato or sticky nightshade in South Africa, viscid nightshade in Australia, and jeweelie in Argentina, is native to warm temperate South America and has been widely cultivated as an ornamental plant. However, the shrub has escaped cultivation and has become invasive in many parts of the world, including Australia where it is recorded from New South Wales (NSW), Victoria, Western Australia and the Australian Capital Territory (ACT). The plant primarily spreads via seeds which are dispersed by animals, such as birds, by human activity, as a contaminant in manure, farm machinery, and in animal feed. Once established, the shrub grows into dense, spiky thickets that supplant natural flora. The plant is also problematic in agricultural areas, reducing livestock carrying capacity in pastures and invading planted fields.

Owing to the significant impacts of the plant in South Africa, attempts have been made to manage *S. sisymbriifolium* since the 1980s. *Solanum sisymbriifolium* has been subjected to both mechanical and chemical controls, but the weed's capacity for coppicing, rapid rate of reproduction, and durable seed banks resulted in limited control. Therefore in 1990, a biological control programme was implemented against this weed, with the release of *Gratiana spadicea*, a leaf-feeding tortoise beetle. The current study aims to investigate the suitability of biological control as a management option for Australia.

RESEARCH TEAM
Prof. Grant Martin, Prof. Sandy Steenhuisen (UFS) and Prof. Martin Hill

STUDENT
Mukololo Khakhu (MSc)

COLLABORATOR
Dr Andrew McConnachie (NSW – DPI, Australia).

The CBC has established excellent cultures of the proposed biological control agent, *Gratiana spadicea* and has been able to germinate and propagate most of the test plants. Preliminary host-specificity trials using first instar larvae in a no-choice set up has revealed that larval mortality is 100% on most of the test plants species with larvae dying within five days and no feeding recorded. This is in contrast to the control plants where larval survival was nearly 100% and the insects did significant damage to *Solanum sisymbriifolium.*

Figure 65. Egg cases and early instar larvae of *Gratiana spadicea* on *Solanum* sisymbriifolium. Photo: Mukololo Khakhu.

INTERNATIONAL WEED PROJECTS

Crystalline ice-plant

The crystalline ice-plant, *Cryophytum crystallinum*, and the slenderleaf ice-plant, *Mesembryanthemum nodiflorum*, are species of 'vygie' (Aizoaceae) indigenous to South Africa and invasive elsewhere. Both species of ice-plant are problematic invaders in the United States and Mexico, where they form dense monocultures in the absence of natural enemies, causing adverse effects on coastal and offshore island ecosystems. In an effort to manage these invasive populations, the CBC continues to collaborate with the United States Department of Agriculture to develop biological control programmes targeting each of these ice-plant species.

Adding to previous molecular work done by MSc candidate, Caitlin Webb, postdoctoral researcher Clarke van Steenderen, and researcher Emma Sandenbergh are investigating the potential origin of invasive *C. crystallinum* populations using a method called restriction-site associated DNA sequencing (RADseq), which they were trained to use by collaborators at CSIRO, Brisbane, Australia. These analyses are still ongoing, but the results so far, coupled with the results obtained by Caitlin Webb, suggest that *C. crystallinum* was transported from the Western Cape of South Africa to the Mediterranean region, and subsequently moved across to North America. As such, native-range surveys to identify potential biological control agents have been conducted along South Africa's west coast.

RESEARCH TEAM
Prof. Iain Paterson and Emma Sandenbergh and Dr Clarke van Steenderen

STUDENTS
Caitlin Webb (MSc), Jackey Mukhawana (MSc) and Karla Jaschke (MSc)

COLLABORATORS
United States Department of Agriculture, San Francisco (Dr Patrick Moran); BBCA Onlus, Rome (Dr Massimo Cristofaro); CSIRO Australia (Dr Dean Brooks).

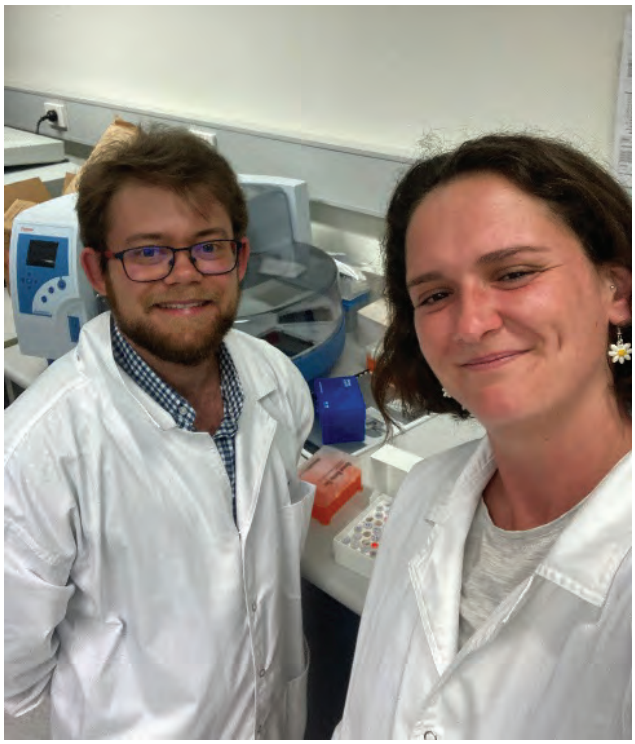

Figure 66. Clarke van Steenderen and Emma Sandenbergh at the CSIRO laboratory in Brisbane, Australia. Photo: Emma Sandenbergh.

Figure 67. Karla Jaschke and Jackey Mukhawana sorting out samples at a site near Port Nolloth. Photo: Emma Sandenbergh.

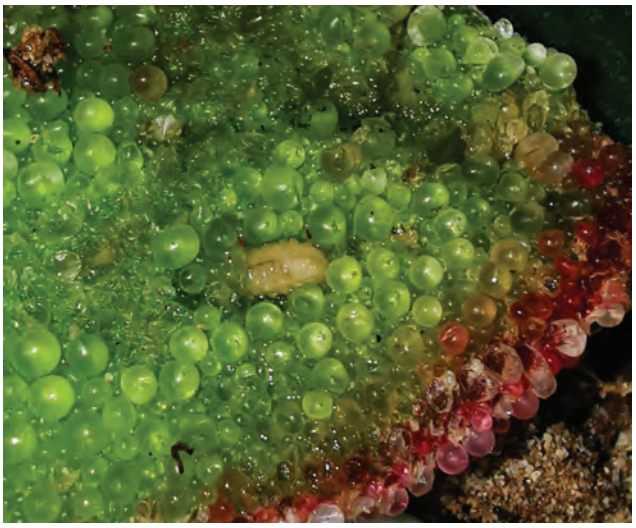

Figure 68. A *Lophocaterinae* sp. larvae on a *Cryophytum crystallinum* leaf. Photo: Karla Jaschke.

The CBC has identified *L. carinerostris* as the most promising potential biocontrol agent for *C. crystallinum*. Adult *Lixus* weevils feed on the plant leaves and oviposit in the stems, where the larvae mine and cause substantial damage. Masters candidate, Jackey Mukhawana, is focusing on the population genetics and field host range of *L. carinerostris*. He is utilizing a variety of genetic techniques to better understand the population genetics and structure of the stem-mining weevil, including Sanger sequencing of the COI barcode gene region, Inter-Simple Sequence Repeats (ISSR) analysis, and RADseq. These analyses are still underway, and the results thus far suggest that *L. carinerostris* is a single species with low genetic diversity and no evidence of local adaptation between collection sites and host plant species.

Figure 69. Adult *Lixus carinerostris* under a dissection microscope. Photo: Karla Jaschke.

Preliminary host-specificity testing has shown that *L. carinerostris* is a *Cryophytum* specialist. As the Americas have very few indigenous Aizoaceae and no native *Cryophytum* species, *L. carinerostris* should prove safe to release in this region. As such, the CBC has sent *L. carinerostris* to the USDA-ARS quarantine facility in San Francisco, USA, where it will undergo further host-specificity testing to ensure its safety and efficacy as a biological control agent for *C. crystallinum*. The results of these studies will aid in the development of a biological control programme for the invasive ice-plant species in the United States and Mexico.

African tulip tree

The African tulip tree, *Spathodea campanulata,* is indigenous to West Africa and has become a serious invasive alien pest in the Pacific Islands. It grows in dense stands that outcompete indigenous plants and is a threat to the endemic species that inhabit the various islands of Vanuatu, Tongo, Fiji and the Cook Islands. The CBC has been working together with Manaaki Whenua for many years, resulting in the release of two biocontrol agents against African tulip tree. The Eriophyid Leaf-galling Mite, *Colomerus spathodeae,* is now established in Tongo, Vanuatu, and the Cook Islands, while the leaf-eating flea beetle, *Paradibolia coerulea,* is established only on Rarotonga, the largest of the Cook Islands.

While the team at Manaaki Whenua is working hard to promote the redistribution of the two agents throughout the Pacific Islands, the CBC team and Green Connexion are working to find biocontrol agents that could reduce the seed set of the plant. Dr Sonia Kenfack-Voukeng, CBC graduate, has been conducting field work in Cameroon that resulted in the discovery of a moth feeding in the pods of the African tulip tree. The damage from the moth kills all the seeds within the pod it feeds on, and is clearly reducing seed production in the indigenous distribution.

RESEARCH TEAM
Prof. Iain Paterson

COLLABORATORS
Quentin Paynter (Manaaki Whenua - LandCare Research; New Zealand) and Sonia Kenfack-Voukeng (Green Connexion; Cameroon)

Figure 70. A moth larvae feeding in the pod of African tulip tree.

Figure 71. An adult *Sinomphisa junctilinealis* that emerged from the pods of African tulip tree.

Figure 72. Pods in the field in Cameroon showing feeding damage from the moth.

The moth has been preliminarily identified as *Sinomphisa junctilinealis* (Crambidae), which has only ever been recorded in the pods of plants very closely related to the target weed, suggesting that it might be suitably host specific to be considered for release in the Pacific.

Import permits and export permits have been secured and the first consignment of the moth was imported into the CBC quarantine in late November when field populations of the moth are highest in Cameroon. A culture of the moth is being maintained in quarantine and host-specificity testing on the closest relatives of African tulip tree will soon be conducted in quarantine. Hopefully *S. junctilinealis* can be added to the list of agents for African tulip tree and contribute towards reducing this alien pest in the Pacific Islands.

BIOLOGICAL CONTROL EFFORTS IN ZIMBABWE

The Centre for Biological Control (CBC) has broadened its reach within the region to enhance the management of invasive alien plants (IAPs), promoting sustainable and effective biocontrol measures. In Zimbabwe, the CBC has revitalised classical weed biological control initiatives that ceased in 2001. Collaborating with the Plant Protection Research Institute (PPRI), under Zimbabwe's Ministry of Lands, Agriculture, Water, Fisheries, and Rural Development, the CBC supported the release of the delphacid planthopper, *Megamelus scutellaris*, as a biocontrol agent against water hyacinth. This marked the first biocontrol release in Zimbabwe in two decades. In addition, the CBC supplied *Cyrtobagous salviniae*, a weevil targeting *Salvinia molesta*, for release at four locations namely Borrowdale Brooke Estate in Harare, Chinyika 2 and Chinyika 3 Dams in Goromonzi, and Shangani Dam in Matebeleland South. As a result of these interventions, *S. molesta* cover declined by approximately 80% at Borrowdale Brooke Estate, Chinyika 2 and Chinyika 3, greatly improving access to these water bodies.

RESEARCH TEAM
Prof. Grant Martin, Prof. Iain Paterson, Prof. Martin Hill, Prof. Julie Coetzee, Dr Kim Canavan and Dr Gerald Chikowore

STUDENTS
Kundai Dube (MSc) and Janet Ncube (PhD)

COLLABORATORS
Dr Philip Weyl (CABI - Switzerland) and Grace Hamah (PPRI - Zimbabwe)

Kundai Dube, an MSc student is collecting baseline data on the distribution and impacts of Australian acacias in Zimbabwe's Eastern Highlands, preparing for biocontrol integration. These invasive wattles have raised concerns regarding habitat degradation for the blue swallow (*Hirundo atrocaerulea*), an intra-African migratory bird, as the acacias encroach on essential breeding areas (Figure 74). Preliminary findings show a 20% increase in wattle invasions in Nyanga National Park over the past two decades, despite clearing efforts, making these species the most significant invasive genus in Zimbabwe's montane grasslands (Figures 74 and 75).

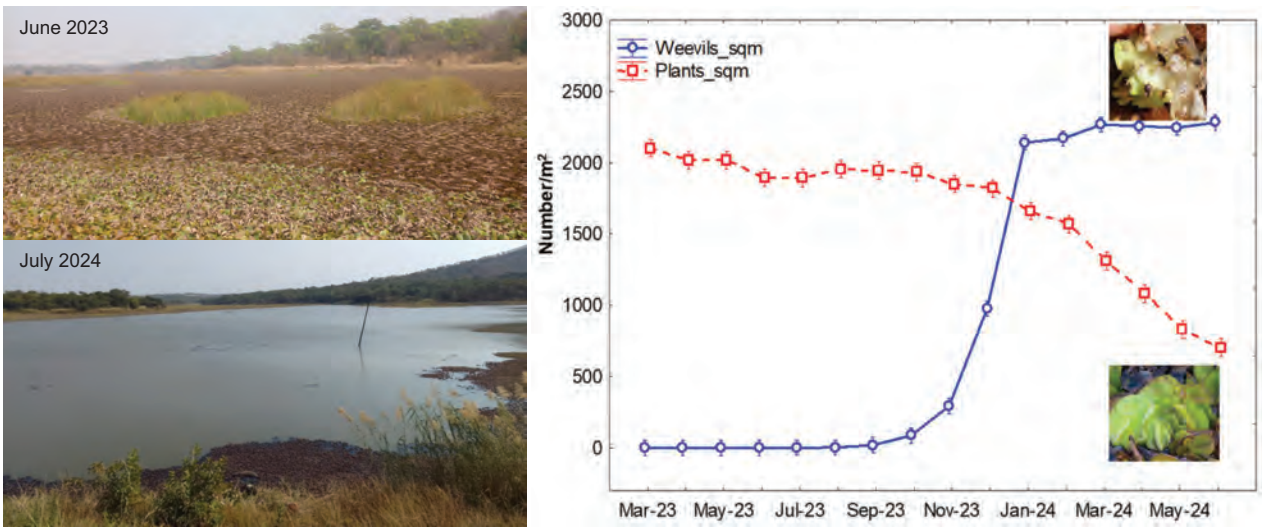

Figure 73. Reduction in *Salvinia molesta* (Kariba weed) following the release of a weevil, *Cyrtobagous salviniae* in Zimbabwe.

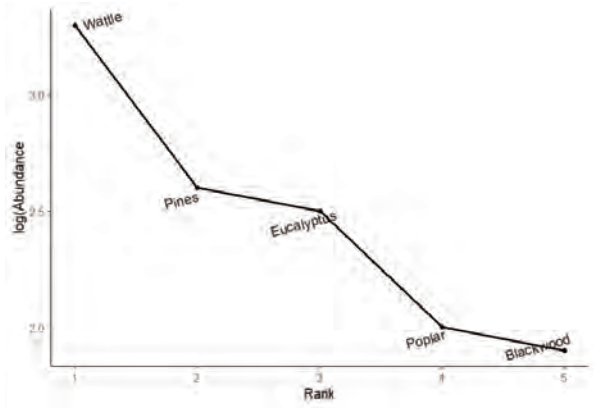

Figure 74. Whittaker rank-abundance curve for invasive alien woody plants in Nyanga National Park, Zimbabwe.

Further work is progressing on biocontrol options for *Hydrocharis laevigata* (Amazon frogbit), an emerging invasive aquatic plant in southern Africa. Baseline data indicate a widespread distribution with dense infestations across Zimbabwe, including areas near Kruger National Park, raising concerns about cross-border spread to Mozambique and South Africa (Figure 76). The *Listronotus* weevil, *Listronotus cinnamomeus*, a potential biocontrol agent identified in Argentina, will soon undergo testing in Zimbabwe, marking the first in-country development of a biocontrol program.

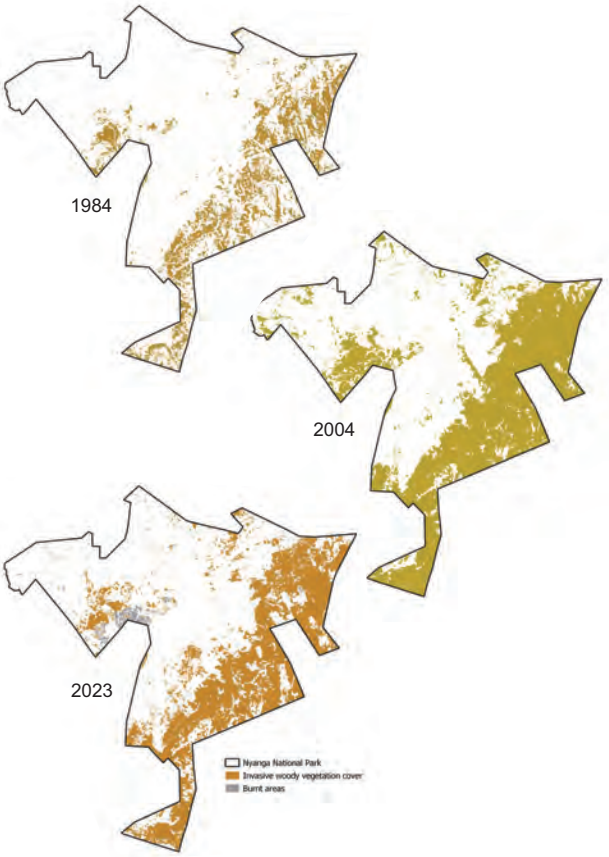

Figure 75. Expansion of woody coverage in montane grasslands in eastern Zimbabwe over the past 40 years.

The CBC's activities in Zimbabwe have been showcased at various events, including a workshop in Harare co-hosted by the CBC and the Food and Agriculture Organization of the United Nations (FAO) to create a national invasive species action plan. Professors Julie Coetzee, Grant Martin and Iain Paterson from the CBC shared scientific insights and successful biocontrol case studies from South Africa that could be adapted cost-effectively for Zimbabwe. Additionally, Zimbabwe's progress in classical weed biological control was presented at the International Symposium for the Biological Control of Weeds (ISBCW) in Argentina, marking Zimbabwe's first participation in this event. Results from the resumed biocontrol programmes were also presented at the 13th Oppenheimer Research Conference in South Africa, and at the Zimbabwe International Research Symposium in Harare.

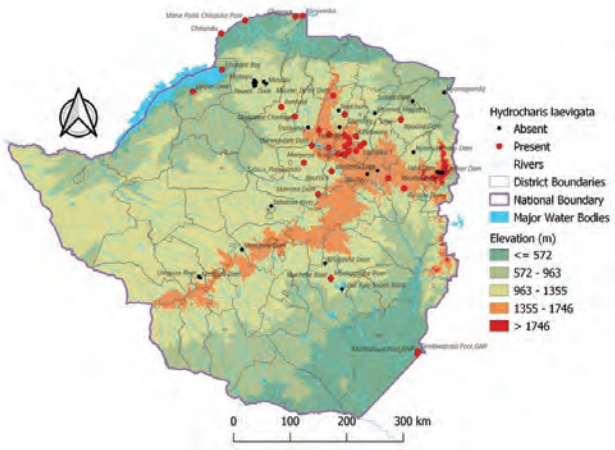

Figure 76. Current distribution of *Hydrocharis laevigata* in Zimbabwe.

Figure 77. Gerald Chikowore (CBC) together with Mr Washington Mubvekeri, Mr Andrew Chamisa and Dr Claid Mujaju (Agricultural Research and Innovation Directorate - Zimbabwe) during the 13th Zimbabwe International Research Symposium.

GRASSES

Globally, invasive grasses pose one of the most serious threats to biodiversity and cause significant economic and environmental damage in invaded ecosystems. Many of these invasive grasses are native to Africa, particularly South Africa. Since 2017, the CBC has developed a number of biocontrol programmes against these species, including the biocontrol of Giant rat's tail grass (*Sporobolus* spp.), African lovegrass (*Eragrostis curvula*) and Gamba grass (*Andropogon gayanus*) in Australia.

More recently, the CBC has been developing biocontrol projects for two grasses that are highly invasive in the USA, namely: Guinea grass (*Megathyrsus maximus*) and Cogon grass (*Imperata cylindrica*). These two projects have not only identified a number of promising biocontrol agents, but have resulted in substantial capacity development for ongoing grass and other biocontrol programmes across the African continent, with components of these programmes being based in other African countries, in addition to the work performed in South Africa.

The foundations have been laid for the potential adoption and development of the first biocontrol programmes against invasive grasses in South Africa. The invasion dynamics, taxonomy and ecology of two highly invasive grass taxa in South Africa, namely *Nassella* spp. and Pampas grass (*Cortaderia* spp.) have been the focus of several exciting student projects. This work will be greatly beneficial for prioritising areas where biocontrol of invasive grasses is most needed in South Africa and in optimising the management of these species. Taken together, these projects are anticipated to result in the development and deployment of multiple grass biocontrol agents both in South Africa and globally.

PROGRAMME HIGHLIGHTS IN 2024

- Native-range surveys on Guinea grass in South Africa and Kenya have identified several prospective biocontrol agents.
- Two of these prospective biocontrol agents have recently been described as new species to science, namely, *Arabukodiplosis vesicaria* Kolesik, and *Arabukodiplosis basalis* Kolesik.
- Host-specificity assessments for a stem-galling midge and a seed-attacking midge have been performed in South Africa, indicating both insects are likely host-specific to Guinea grass.
- Native-range surveys have commenced in South Africa and Kenya for possible biocontrol agents for Cogon grass.

Guinea grass

Megathyrsus maximus is a perennial African grass that has been introduced in many regions outside of its native distribution for pasture development. It has become a serious environmental pest in Texas, USA, where it reduces grazing capacity, alters natural fire regimes and negatively affects native wildlife populations. Previous biocontrol surveys had been performed in West Africa and Kenya. However, DNA

RESEARCH TEAM
Prof. Iain Paterson, Dr Guy Sutton and Mrs Phillippa Muskett

STUDENT
Mr Benjamin de la Fontaine (MSc student)

COLLABORATORS
University of Texas (Rob Plowes, Aaron Rhodes, Colin Morrison) and Mpala Research Centre (Aimee Gaitho)

samples provided by the CBC indicated that Guinea grass populations in Texas likely originated from southern Africa. This resulted in the CBC initiating a collaboration with the University of Texas in 2019 to identify potential biocontrol agents for Guinea grass from southern Africa, and continue surveys in Kenya. These surveys have identified several possible biological control agents, including multiple stem-galling midges (Cecidomyiidae), a stem-boring wasp (*Tetramesa* sp.; Eurytomidae) and a suite of seed-galling midges (Cecidomyiidae). Two of the stem-galling midges have recently been formally described as two new species to science, namely: *Arabukodiplosis vesicaria* Kolesik and *Arabukodiplosis basalis* Kolesik (Kolesik et al., 2025). The *Tetramesa* sp. was rejected as a possible biocontrol agent for Guinea grass as it was not suitably host specific based on our field and greenhouse-based host-specificity assessments.

The first midge species *A. vesicaria* (Figure 78), has been recorded in abundance across many field sites in both South Africa and Kenya, and forms conspicuous galls on the stems of *M. maximus*. Preliminary field surveys indicate that this midge species appears to utilise only *M. maximus* under field conditions in both Kenya and South Africa, despite surveying a range of closely-related and structurally similar grasses in both regions. This indicates a high degree of specificity. The galls appear to act as a nutrient sink, depleting the plant of its resources and stopping the plant from producing seed.

A viable culture of *A. vesicaria* was established under greenhouse conditions in KwaZulu-Natal in early 2024, which allowed us to evaluate the host-specificity and thus its suitability as a biological control agent of this species under controlled conditions. Ten non-target grasses that grow sympatrically with *M. maximus* have now been subjected to no-choice host-specificity testing under greenhouse conditions in South Africa.

Arabukodiplosis vesicaria only oviposits and produces F_1 progeny on the small and large morphs of Guinea grass, with no oviposition or F_1 progeny recorded on any of the non-target grass species. The combined field host-range and greenhouse-based host-range assessments indicate that *A. vesicaria* is likely restricted to utilizing *M. maximus*, while limiting seed production, and thus looks like a very promising candidate agent. Efforts are underway to establish a viable culture of *A. vesicaria* in quarantine in South Africa where additional no-choice testing will be conducted for native grasses from the south-east USA, focusing on native grasses from Texas.

Figure 78. Typical gall morphology of *Arabukodiplosis vesicaria*. Photo: Iain Paterson.

Figure 79. Typical gall morphology of an undescribed stem-galling midge on Guinea grass. Photo: Iain Paterson.

A second stem-galling midge species (Figure 79), which is an undescribed species, potentially belonging to the newly erected *Arabukodiplosis* genus (Peter Kolesik, pers. comm.), has been recorded in abundance at many field sites in both South Africa and Kenya. It is distinguished from *A. vesicaria* by the conspicuous tube connecting the gall to the tiller (which is absent for *A. vesicaria*), and the adults being darker cream in colour, rather than white/cream. Field surveys have indicated that this midge species appears to feed on an array of

non-target grass species, in addition to *M. maximus*, under field conditions in both Kenya and South Africa. Notably, this species has been recorded on both the large morphotype of *M. maximus*, as well as the very closely related grass species, *P. deustum* Thunb. Galls have been found on these non-target grasses both at sites where the non-target species co-occur with the small morphotype of *M. maximus*, in addition to sites where *M. maximus* is absent. Moreover, gall densities are often 2-10 times higher on the large morphotype of *M. maximus* and *P. duestem* than on the target weed. This suggests that the undescribed midge is oligophagous and is not suitably host-specific for further consideration as a possible biocontrol agent for this programme.

Figure 80. (a) Typical gall morphology of *Arabukodiplosis basalis*, and (b) greenhouse set-up at Gede near the Arabuko-Sokoke State Forest in Kenya. Photo: Rob Plowes/Colin Morrison.

A meristem-galling midge was collected in the Arabuko-Sokoke State Forest in Kenya in June 2022 (Figure 80a). This midge was recently described as *Arabukodiplosis basalis* Kolesik sp. nov. (Kolesik et al., 2025). Single galls on a plant were sometimes observed, but most commonly between three and eight galls were found on a plant, with some plants having over 35 galls. The galls appear to develop at the basal meristem of the grass, presumably forming galls where stems would usually originate. Field surveys between 2022 and 2024 have indicated that this midge species appears to utilise only *M. maximus* under field conditions at Arabuko-Sokoke, despite surveying a range of closely related and structurally similar grasses.

Notably, the large morphotype of *M. maximus*, as well as the very closely related grass species, *P. deustum* Thunb., occur in sympatry with the small morphotype of *M. maximus*. These grasses were searched for midge galls, but no galls that could be attributed to the insect were found on the non-target grass species, despite an abundance of galls on small morphotype *M. maximus* growing adjacent to them. This suggests that the undescribed midge may be monophagous and restricted to feeding on the small *M. maximus* morphotype. Multiple field trips to Kenya were performed in 2024 to attempt to establish a greenhouse culture of *A. basalis* at a location near the Arabuko-Sokoke State Forest (Figure 80b). A nursery of plants has been developed since July 2024, and a field trip in November/December 2024 will attempt to establish the *A. basalis* culture in the greenhouse. Field trips and preliminary attempts to establish the *A. basalis* culture have allowed us to learn important information about the biology of the insect, which will be highly beneficial for optimising the rearing methods for *A. basalis*. Once a greenhouse culture is established, no-choice host-specificity testing will be initiated.

The next candidate agent(s) are a suite of seed-attacking midges (Diptera: Cecidomyiidae) (Figure 81). In addition to *M. maximus*, we have reared morphologically similar seed-attacking cecids from eight sympatric grasses across the *Panicum, Setaria*, *Urochloa*, *Melinis* and *Cenchrus* genera. However, the cryptic morphology of the seed midges found on the different genera of grasses collected precluded any assessment of their host-range and suitability as biocontrol agents using traditional morphological identifications. As such, we undertook a detailed genetic DNA barcoding study of these seed midges in 2024. This study indicated that at least three seed-attacking midge species are associated with *M. maximus* in South Africa. At least one of these midges (hereafter 'MSP1') does not group with the midges

collected from other non-target grasses indicating a possibly host-specific relationship between this midge species and *M. maximus*. The other two midge species associated with *M. maximus* (hereafter 'MSP2' and 'MSP3') clustered with representative midge species DNA sequences from other non-target grasses (e.g. *Urochloa mutica* and *Melinis repens*). Both MSP2 and MSP3 are considered to probably represent the same midge species as recorded on *U. mutica* and *M. repens*, indicating that they are unlikely to be suitably host-specific to be considered further as potential biocontrol agents for *M. maximus*.

Given the findings of the DNA barcoding study and the field host-specificity assessments, we focused on performing no-choice oviposition trials for seed midge MSP1 in 2024. These trials were designed to assess whether the MSP1 cecid will oviposit on *M. maximus* and/or non-target grasses. To date, 11 non-target grasses have been tested, in addition to offering the midges *M. maximus* seeds (we offered both small and large morph Guinea grass seeds, separately). Guinea grass was consistently oviposited on by MSP1 females. However, none of the 11 non-target grasses have been oviposited on to date. These findings indicate that MSP1 may be restricted to only ovipositing on *M. maximus*, which is promising for its development as a biological control agent. No-choice host-range assessments for MSP1 were initiated in mid-2024, offering whole potted plants of *M. maximus* and two closely-related native African grasses, *Setaria sphacelata* and *Setaria incrassata*, to 20 MSP1 cecids. Each grass species was tested with at least five replicates. To date, only three of the five replicates for each grass species have been completed. MSP1 was only able to complete development on *M. maximus*, with all three *M. maximus* replicates producing 10+ F_1 generation adults, while no F_1 adults were recorded from any of the *S. sphacelata* and *S. incrassata* replicates. MSP1 is suitably host-specific for further detailed testing as a potential biological control agent of *M. maximus*.

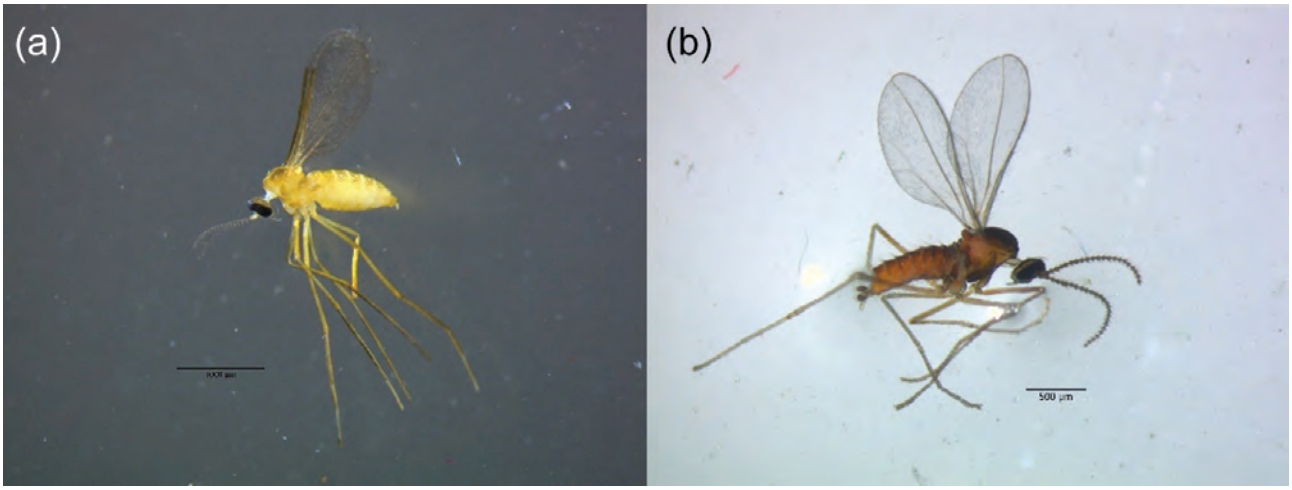

Figure 81. Representative specimens of seed-cecid (a) MSP1 and (b) MSP2 recorded on Guinea grass in South Africa. Photo: Benjamin de la Fontaine.

Cogon grass

Cogon Grass (*Imperata cylindrica* (L.) Beauv.) is one of the ten worst weeds in the world, a federally listed noxious weed country-wide in USA, and one of the most problematic invasive weeds in the south-eastern USA. Cogon grass negatively impacts native plant communities, aggressively competes with other vegetation for soil nutrients, alters the rates of decomposition of native grasses, and alters natural fire cycles. In 2023, an exciting new biological control project was initiated as a collaboration between the CBC, the United States Department of Agriculture (USDA) and CABI Kenya in 2023.

RESEARCH TEAM
Prof. Iain Paterson and Dr Guy Sutton

COLLABORATORS
Dr. Gregory Wheeler (United States Department of Agriculture [USDA]) and Ivan Rwomushana, Duncan Chacha (CABI Kenya)

Figure 82. Dr Gregory Wheeler (front, USDA) and Dr Guy Sutton (back, CBC) searching for possible biocontrol agents on Cogon grass near Kwale in eastern Kenya. Photo: Prof. Iain Paterson.

During 2023 and 2024, more than 50 surveys of the natural enemies associated with Cogon Grass were performed across South Africa. To date, while exploratory feeding has been observed at some sites, no natural enemies have been recorded. This probably indicates that Cogon grass is not native in South Africa, and suggests that South Africa is unlikely to be a suitable area to search for possible biocontrol agents of Cogon grass.

Subsequently, in June 2024, surveys were conducted in southern Kenya in search of possible biocontrol agents for Cogon grass, in collaboration with CABI Kenya (Figure 82). These surveys ranged from Homa Bay in the far west of the country to Shimba Hills just outside Mombasa on the east coast. An abundant planthopper was found feeding externally on the leaves of the plants at a site near Oyugis in the western part of Kenya. An armoured scale insect was collected and was abundant at one of the field sites visited near Kwale in the eastern part of Kenya. The scale feeds on the rhizomes of the plant and is therefore promising because the rhizomes are considered important in driving the invasion of the plant in the USA. A scale insect that attacks the rhizomes of *Arundo donax*, one of the few grasses that has been targeted for biological control, has successfully established and is reducing populations of the weed in USA. This suggests that a similar agent on Cogon grass may be successful. The planthopper is also a possible candidate but, given the type of damage that it does to the plant, and the part of the plant that it attacks (the leaves), it is considered less promising than the armoured scale.

Further surveys for possible biocontrol agents are scheduled for 2025 in Uganda where Cogon grass may be more widespread and abundant than it is in Kenya. If the armoured scale is present in Uganda, it will be an indication that it is a promising candidate agent, and we will attempt to import it into quarantine in South Africa for further studies.

Nassella spp.

In collaboration with the ARU and the UFS, the CBC is continuing research on the alien grasses, *Nassella* in South Africa. Lumko Mboyi's project studies the invasion patterns and impacts of *N. tenuissima* in the Eastern Cape Drakensberg (Figure 83). The outcomes of this project will allow insight into which areas control efforts should be concentrated. Additionally, the project will shed some light on the impacts the species has on plant biodiversity in the area.

RESEARCH TEAM
Dr Kim Canavan, Dr Anthony Mapaura, Prof. Vincent Ralph Clark and Prof. Sandy-Lynn Steenhuisen (University of the Free State (UFS) and Afromontane Research Unit (ARU))

STUDENT
Lumko Mboyi (MSc student, UFS and ARU)

COLLABORATORS
Mountain Zebra Camdeboo Protected Environment

To further raise awareness about the threat of *Nassella* in the Eastern Cape, the CBC, Mountain Zebra Camdeboo Protected Environment and the University of the Free State chaired a webinar on 16 April 2024 which set out to help disseminate information on identifying the grasses, outlining their impacts, and discussing management strategies. The event drew significant interest, with over 50 registrants from a range of organisations, including seven academic institutes, two government departments, seven land management companies, land owners, and more.

The work being done on *Nassella* in the region will enhance the available knowledge regarding a seemingly forgotten problem species and have implications for conservation planning and rangeland management.

Figure 83. MSc student, Lumko Mboyi, standing in a patch of *Nassella tenuissima* on a farm in Barkly East, Eastern Cape. Photo: Anthony Mapaura.

Pampas

In collaboration with UFS and SANBI, the CBC supervised a project on pampas grasses in South Africa, led by MSc student, Thembelihle Mbele. The project examined the current status of the two alien invasive pampas grasses, *Cortaderia selloana* and *C. jubata* in South Africa. Despite legislation prohibiting the cultivation and trade of pampas, including the flowers, they continue to be a popular choice in décor, particularly for weddings. The study looked at seed viability in flowers from naturalised populations and those sold within the floriculture industry. Seed viability was confirmed for both sources and, in particular, flowers sold informally through street vendors often have a higher rate of viability. It is therefore likely that the use of flowers is an important pathway for spread of the species and improved enforcement of the legislation is needed.

A genetic study was also conducted and found that only the two *Cortaderia* species occur in South Africa. *Cortaderia jubata* was found to be clonal, with only one lineage found in study sites in South Africa. *Cortaderia selloana* was found to be more widely distributed across the country with populations being genetically similar.

RESEARCH TEAM
Dr Kim Canavan and Prof. Sandy-Lynn Steenhuisen (UFS and ARU)

STUDENT
Thembelihle Mbele (MSc, SANBI, UFS)

COLLABORATORS
SANBI, University of Oviedo, Spain

Thembelihle also wrote a popular article published in *SA Dry Beans* magazine to raise awareness on this topic, see article using this link: pubhtml5.com/xsusq/mcwe.

The team are collaborating on a global project on *C. selloana* led by Dr. Adrián Lázaro-Lobo and Dr. Borja Jiménez-Alfaro. The project is looking into biological patterns of the global invasion of *C. selloana* with the intention of providing information to better manage the species in the future. Populations were collected in South Africa and sent to Spain for further analysis. This work also involved contributing to a published monograph on *C. selloana* to provide a comprehensive resource on all aspects of the plants including taxonomy, environmental impacts and management options.

Figure 84. MSc student, Thembelilhe Mbele, collecting *Cortaderia selloana* in Ladybrand, South Africa. Photo: Kim Canavan.

AGRICULTURAL ENTOMOLOGY

The CBC's Agricultural Entomology Research Group has had an exceptional year, advancing biological control strategies to address key citrus pests. From thrips to moths, the team has focused on developing environmentally friendly alternatives and enhancing existing pest-management techniques. Their research spans a wide range of topics, including understanding natural enemy and pest dynamics in orchard-adjacent fields, identifying additives to improve the efficacy of virus-based biopesticides, and exploring innovative approaches to sustainable pest control. This diverse and impactful work has been driven by a dedicated team of PhD and MSc students, postdoctoral fellows, and staff, who together have presented their findings at four national and international conferences, published four peer-reviewed research articles, and celebrated the graduation of three Masters and one Doctoral student. Excitingly, this year also saw the establishment of a cold treatment facility, which will greatly accelerate our understanding of critical cold treatment protocols for managing several pest species, including several mealybug species of phytosanitary importance. The team is immensely proud of their accomplishments this year and looks forward to building on this year's successes and knowledge.

PROGRAMME HIGHLIGHTS IN 2024

- Conferences: SIP 2024; Citrus symposium 2024; ICE 2024, and the RU postgraduate conference 2024.
- Installation of new cold rooms at the Waainek Research Facility.
- Four peer reviewed publications.
- Graduations: three MSc, one PhD.

Development of an advanced qPCR technique for the enhanced and accurate enumeration of the baculovirus biopesticide CrleGV-SA.

RESEARCH TEAM
Dr Marcel van der Merwe, Prof. Martin Hill, Dr Michael Jukes and Eben Mundell

Lepidopteran pests pose a significant threat to the South African citrus industry, particularly the false codling moth (*Thaumatotibia leucotreta*), a key phytosanitary pest in international markets. An integrated pest management (IPM) programme is employed to manage these pests, with baculovirus-based biopesticides serving as a crucial component. Cryptophlebia leucotreta granulovirus (CrleGV-SA) has been a cornerstone of this IPM programme for over two decades. Accurate quantification of virus particles is essential for effective field application. While traditional methods, such as dark-field microscopy are widely used, they suffer from subjectivity, are time-consuming, and have limited sensitivity. As a laboratory technique that amplifies and quantifies specific DNA sequences in real-time, quantitative PCR (qPCR) offers a more accurate, sensitive, and efficient alternative for quantifying baculoviruses. It is a variation of traditional PCR, with the added ability to monitor the reaction progress using

fluorescent dyes or probes. qPCR is highly sensitive, allowing for precise quantification. This project aims to develop a robust qPCR protocol for quantifying CrleGV-SA, contributing to improved precision and reliability in biopesticide application and pest management. A target fragment from CrleGV-SA has been successfully amplified using external primers and ligated into the pMini-T™ 2.0 vector. Sequencing has confirmed the correct insert in the plasmid. The qPCR assay has been optimised, and initial runs have been completed, using only the standards to verify the assay's functionality. Experimental runs are now underway with formulated CrleGV-SA. Additionally, this project plans to replicate methods and samples at River Bioscience and Rhodes University to assess protocol robustness with different equipment and reagents.

The isolation, identification, and characterisation of novel insect viruses for the control of emerging agricultural pests

RESEARCH TEAM
Prof. Martin Hill, Prof. Sean Moore, Dr Michael Jukes and Prof. Caroline Knox

STUDENT
Tahnee Bennett (PhD)

The intensification and expansion of agriculture are among the most prominent global changes driven by human activity (Matson et al., 1997). As the human population continues to grow, one of the major global challenges is ensuring adequate food production. Insects play an important role in crop production because of the ecosystem functions that they provide, which are often disrupted in agricultural fields. The modification of habitats by humans, such as selecting crops for higher yield, larger size, or those that have higher nutritional value, and the cultivation of monocultures for maximum productivity all contribute to the emergence of insect pests. Additionally, changing climatic conditions or changes in farming practices may result in changes in the status of certain pests in different agricultural crops.

In various studies, viruses that are harboured by several agriculturally important pests in South Africa, including *Plutella xylostella*, *Phthorimaea operculella* and *Thaumatotibia leucotreta*, have been isolated and biologically characterised, and some are now commercially available as biopesticides. The RNA virus family *Dicistroviridae* are viruses that infect arthropods, for example, a virus from this family is the Cricket paralysis virus (CrPV) that was first isolated from Australian field crickets. This virus is known to infect both crickets and fruit flies. As such, the use of this virus may find application in the management and control of fruit fly.

To safeguard crop production in South Africa, continued bioprospecting for novel biological control options, particularly viruses, against major, minor, and emerging insect pests is important. This project aims to isolate, identify, and characterise novel viruses from various insect pests that already impact, or have the potential to impact one or more important agricultural crops. To date, symptomatic larval cadavers of *Serrodes partita*, *Thaumatotibia batrachopa*, and *Ectomyelois ceratoniae* have been collected and baculovirus occlusion bodies (OBs) were purified from these samples.

Genomic DNA (gDNA) was extracted from the purified OBs and was used for PCR amplification of the *polyhedrin/granulin* gene from multiple samples, and the *late expression factor 8* (*lef-8*) and *late expression factor 9* (*lef-9*) genes from select samples. Sanger sequencing of the PCR amplicons was conducted, followed by bioinformatic analysis. Sequencing results suggest that a novel baculovirus was isolated from *S. partita* larvae. The virus was identified as an *Alphabaculovirus*, grouping closely to Lymantria dispar MNPV and Lymantria xylina NPV, with Kimura two-parameter distance matrices indicating this virus to be a novel species, hereafter referred to as SepaNPV. Whole genome Illumina sequencing was conducted using the SepaNPV genomic DNA and a *de novo* assembly was conducted to reassemble the genome sequence, using the generated NGS data. Results indicate a genome size of 129953 bp, with a GC content of 54.9 %, and approximately 172 ORFs.

Infection assays were also conducted to test the host range of SepaNPV against four potential host

species. Data indicate that *T. leucotreta, Helicoverpa armigera, Spodoptera frugiperda* and *Eldana saccharina* are not susceptible. Multiple *T. batrachopa* larvae were also evaluated and shown to be infected with CrleGV. Furthermore, an RNA isolation protocol was established using Invitrogen™ Phasemaker™ Tubes in conjunction with the Invitrogen™ TRIzol™ reagent for RNA isolation and a two-step reverse transcription polymerase chain reaction (RT-PCR) amplification. The protocol was used to isolate RNA from symptomatic *Acheta domesticus* samples. None of the cricket samples was infected with CrPV.

Figure 85. Transmission electron micrograph of sectioned viral OBs isolated from *S. partita* larval cadavers.

Fruit fly attraction to volatile compounds produced by insect-associated yeast strains

Fruit flies (Diptera: Tephritidae) are known pests of many economically important agricultural crops worldwide. Three fruit fly species of concern in the sub-Saharan region are the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann); the Natal fruit fly, *Ceratitis rosa* Karsch; and the oriental fruit fly, *Bactrocera dorsalis* (Hendel). Fruit flies cause considerable physical damage to the fruits, making them non-marketable. Furthermore, its phytosanitary pest status results in increased export costs to ensure fruits are not infested, thus having a direct and indirect impact on the economy.

The bait application technique (BAT) and the sterile insect technique (SIT) are the commonly used methods to control fruit flies in South Africa. However, the SIT is selectively used in areas such as the Western Cape compared to BAT, which is used widely throughout the country. The bait application technique uses a combination of an attractant and an insecticide. The only commercialised bait insecticide, HymLure, uses a protein hydrolysate as an attractant. However, the degree of attraction to the protein differs among fruit fly species.

RESEARCH TEAM
Prof. Caroline Knox, Dr Marcel van der Merwe, Prof. Martin Hill and Prof. Sean Moore

STUDENT
Siviwe Tole (PhD)

Previous studies have reported interactions between yeast and fruit flies. Yeasts are essential in their dietary requirements, playing a role in larval development and behaviour. This study aims to isolate novel yeast strains from fruit flies for a better understanding of the development and behaviour of these pests. The potential isolation of these yeast strains could be used as biological agents to control these pests in the field.

Figure 86. Adult Natal fruit fly, *Ceratitis rosa*, collected from laboratory culture based in Nelspruit. Photo: Siviwe Tole.

For this study, fruit flies were collected from orchards in Addo, and adult fruit flies were also collected from laboratory cultures of *C. capitata*, *C. rosa*, and *B. dorsalis* maintained in Nelspruit.

The samples were processed and streaked on yeast peptone dextrose (YPD) agar plates containing chloramphenicol and grown at 25 °C for 48 hours. Colonies were selected and grown in YPD broth before gDNA was extracted using the YeaStar™ Genomic DNA kit. The identification of the isolated yeasts is underway using PCR amplification of the ITS region and D1/D2 domain of LSU. This will be followed by sequencing and determining whether any of the isolated yeast species influence the foraging behaviour of *C. capitata*, *C. rosa*, and *B. dorsalis* flies.

Figure 87. Yeast isolates streaked on Chloramphenicol Agar and grown at 25 °C for 48 hours. Photo: Siviwe Tole.

Developing cold treatment schedules for controlling mealybug species (Hemiptera: Pseudococcidae) of phytosanitary significance to the South African citrus market.

Cold storage disinfection has become a viable post-harvest treatment for perishable citrus products, offering an effective quarantine disinfestation alternative to chemical fumigation. Mealybug pests pose a significant challenge for citrus exports as many major markets have zero tolerance for their presence on exported citrus. Exploring the efficacy of cold treatment as a biological control technique for managing key mealybug species of phytosanitary importance in the South African citrus industry offers viable insights into post-harvest pest control methods.

RESEARCH TEAM
Prof. Martin Hill, Dr Candice Coombes, Dr Reyard Mutamiswa and Prof. Sean Moore

STUDENT
Deric Vershiyi Tanka (PhD)

This study examined the effectiveness of cold treatment schedules against key mealybug species and assessed their inherent basal thermal tolerance to withstand varying extreme conditions. The efficacy of cold

treatment schedules was measured at 3 °C from 2 to 22 d in 4-day intervals to assess their impact on various life stages of *Planococcus citri.* To assess the inherent basal thermal tolerance of mealybugs, laboratory-reared 3rd instar and adult *P. citri, Pseudococcus longispinus,* and *Pseudococcus calceolariae* were exposed to temperatures ranging from 5 °C to -13 °C for 0.5, 2, and 4 hours to evaluate survival rates. Mortality across all life stages showed significant differences, depending on the duration of exposure. At 3 °C for 18 days, 100% mortality was achieved for all *P. citri* life stages. Mortality rates above 90% were observed after 14 days of exposure. Eggs, 3rd instars, and adults showed greater cold tolerance than 1st and 2nd instars, with 100% mortality of the 1st and 2nd instars recorded after 10 days of cold treatment. Lower temperatures and longer exposure durations significantly reduced survival for all species and life stages. All mealybug species and life stages achieved 100% mortality at -13 °C, even at the shortest exposure duration of 0.5 hours. The 3rd instars of all species exhibited greater cold tolerance than adults across all temperature and exposure conditions.

Pseudococcus calceolariae and *P. longispinus* demonstrated a lower lethal threshold, suggesting a survival advantage over *P. citri* under extreme cold exposure. This suggests that under cold treatment schedules at 3 °C, *P. calceolariae* and *P. longispinus* require longer exposure durations than *P. citri* to achieve 100% mortality. Ongoing trials of cold treatment schedules on *P. calceolariae* and *P. longispinus* at the Waainek Research Station in Makhanda will further assess treatment efficacy at 3 °C for 22 d.

The results of this study will support the use of cold treatment schedules at 3 °C, offering an effective systems approach with a lower risk of fruit chilling injury. This approach enhances the effectiveness of cold treatment within an integrated pest management framework.

Investigating release ratios in an FCM SIT programme

RESEARCH TEAM
Dr Candice Coombes, Prof. Sean Moore and Prof. Martin Hill

STUDENT
Michael Mathenge Githae (PhD)

The Sterile Insect Technique (SIT) for FCM (false codling moth) was first commercially implemented in South Africa in 2007. It is now widely practised in various regions of the country, where it is strongly recommended as a key component of area-wide integrated pest management (AW-IPM). The success of SIT depends on achieving a high ratio of sterile males to wild males in targeted release areas. The current standard ratio is 10:1, although higher ratios are often achieved and may yield better results. This study aimed to evaluate the effectiveness of higher release ratios and population growth rate of FCM in field and laboratory cage studies.

While the field trials produced limited and inconclusive results, the laboratory trials demonstrated that release ratios above 40:1 significantly reduced both fruit damage and the population growth rate of FCM. Additionally, various combinations of treated and untreated FCM resulted in some fruit infestations in the laboratory. However, any combination involving a treated male or female FCM resulted in some population suppression.

Since SIT is an AW-IPM strategy, field data suggest that combining SIT with parasitoid releases enhances control more effectively than using either method alone. This necessitated examining the synergistic relationship between the egg parasitoids, *Trichogrammatoidea cryptophlebiae* and SIT. A laboratory study assessed the acceptability and suitability of FCM eggs from higher release ratios for parasitism by the egg parasitoids. It was found that these parasitoids could successfully parasitise eggs from higher release ratios of sterile to fertile FCM than 10:1, providing additional hosts for parasitoid development and contributing to greater suppression of FCM populations in citrus orchards. X Sterile Insect Technique (Pty) Ltd (XSIT) conducts dual-sex releases of sterile FCM in citrus orchards. Subsequently, pre-release matings have been reported, negatively impacting the effectiveness of SIT. The study examined pre-mating incidence at different stages of sterile FCM production. Results indicated that higher levels of mating, as indicated by the presence of spermatophores and mated female FCM, occurred at the irradiation and release stage in the Sundays River Valley region. This suggests that improvements are needed at these stages to minimise moth activity and prevent pre-release mating.

Development of parasitism-related intervention thresholds for the management of red scale on citrus

The California red scale, *Aonidiella aurantii*, is a key pest of citrus in South Africa. However, biological control can be very effective in contributing to red scale suppression. Establishing intervention thresholds based on parasitism levels could decrease the reliance on chemical sprays. This study aims to develop parasitism-related intervention thresholds to help manage red scale effectively. Factors considered in developing these thresholds are level of infestation, proportion of live and dead scale, percentage parasitism, parasitoid species, fruit infested with live red scale at harvest, cultivar, time of harvest, and climatic conditions.

Red scale infestation was monitored in 15 orchards with 11 different citrus cultivars from the first appearance of red scale on green twigs and fruit, until harvest. Monitoring involved examining 10 fruit on each tree in a transect through the orchard every two weeks. Twenty infested fruit from each orchard were collected for microscopic inspection to identify the status of the scale (live, dead, parasitised, super-parasitised, mutilated). In the first study season, red scale infestation ranged from 0% to 96%, with infestation generally increasing from November to March. Parasitism levels varied from 0% to 31%, generally increasing from January to March, with a particularly notable rise in March.

RESEARCH TEAM
Prof. Martin Hill and Prof. Sean Moore

STUDENT
Vhuawelo Simba (PhD)

Parasitoid species were a significant predictor of parasitism rates, with *Aphytis africanus* and *Comperiella bifasciata* the dominant parasitoid species. A previously undescribed endoparasitoid of red scale was discovered. The study will continue into a second season.

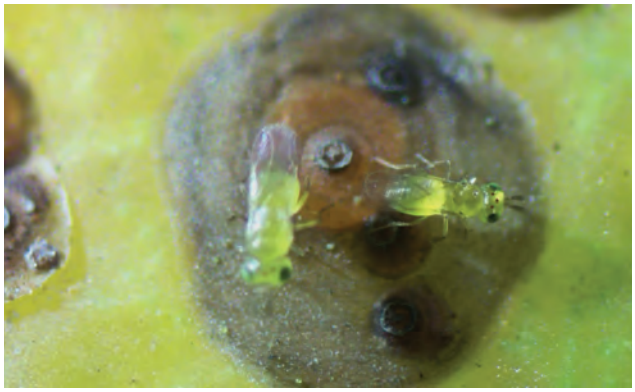

Figure 88. *Aphytis* species parasitoids probing red scale. Photo: Vhuawelo Simba.

A multi-faceted holistic approach towards sustainable IPM of citrus thrips

Citrus thrips, *Scirtothrips aurantii*, is the most important cosmetic pest of citrus in southern Africa owing to a) its short generation time, b) its ability to cause a large amount of fruit damage in a short space of time, c) the permanence of the damage, and d) its notable ability to develop resistance to insecticides.

Thrips control is undermined by the suppression of its effective natural predatory mite enemies by current spray programmes emanating from mandatory calendar sprays for citrus black spot, *Phyllostricta citricarpa*. The sprays result in the increased use of broad spectrum long-residual thripicides until later in the season, which in turn results in secondary pest problems, most notably mealybug outbreaks. Consequently, IPM implementation is undermined.

RESEARCH TEAM
Prof. Martin Hill and Prof. Sean Moore

STUDENT
Luke Cousins (PhD)

This study, which is still in its first year, aims to investigate a variety of thrips control methods that do not involve the use of chemical pesticides. Such methods include studying the effect that modification of the fertilisation programme (particularly nitrogen levels), as well as

intensified season-long pruning management, has on thrips levels. The study also aims to identify a number of possible thrips repellents, including predatory mite extracts, which could have potential non-consumptive effects. Enhancing the effectiveness of predatory mites through various types of orchard cover crops and the application of supplementary food sources is an additional objective.

Pruning trials began on a farm in the Sunday's River Valley in August 2024. Treatments included unpruned trees, trees pruned once without flush regrowth management, and trees pruned with flush regrowth management. Thrips populations have been monitored using yellow sticky traps, replaced fortnightly. Nutrient manipulation trials began in October 2024, making use of young nursery trees (Delta Valencia cultivar). Sixty trees were acquired from a nursery in Kirkwood, placed into a greenhouse at the CBC facility in Uitenhage and re-potted with a varying range of controlled-release fertiliser treatments in an attempt to manipulate the leaf nitrogen content during the season. The greenhouse trees will be individually netted and inoculated with field-collected thrips, and additional detached leaf bioassays will be conducted to assess thrips response to the fertiliser treatments.

The impact of conservation landscapes on pest and natural enemy occurrence in adjacent citrus orchards.

Figure 89. Shaun Manzini placing a pitfall trap to trap ground-dwelling arthropods in the remnant vegetation surrounding the citrus orchard.

RESEARCH TEAM
Prof. Martin Hill and Prof. Sean Moore

STUDENT
Shaun Manzini (PhD)

Over the last century, agricultural intensification has increased crop yield, increased chemical inputs, reduced landscape heterogeneity, and significantly contributed to biodiversity loss and ecosystem services. Undoubtedly, the decline of arthropod diversity is linked to agricultural intensification, thus posing a severe threat to human well-being and ecosystem function, considering their critical functional role in ecosystem processes and functions. Beneficial arthropods, including predators and parasitoids, aid in pest control. All these ecosystem functions contribute to maintaining agricultural production and reducing the need for pesticide input.

Currently, one of the critical global challenges is balancing biodiversity conservation and sustainable food production. In southern Africa, the citrus industry has successfully implemented, adopted, and documented sustainable practices such as biological control and an integrated pest management (IPM) programme. Lately, however, these sustainable practices have been undermined in the industry by calendar sprays used for citrus black spot (CBS), *Phyllosticta citricarpa*. Although the use of calendar sprays successfully reduces the damage caused by CBS, the improper use of insecticides affects non-target species, such as beneficial insects. Therefore, there is a need to

develop a systematic approach to aid in transitioning back to sustainable IPM practices in citrus. One of the possible solutions is habitat management to attain biodiversity conservation and conservation biological control. There is mounting evidence showing the benefits of this approach through increased biological control and reduced pest pressure in agricultural fields. Therefore, the aim of this study is to quantify the impact of conservation landscapes on pests and natural enemy occurrence in adjacent citrus orchards. Specifically, the study addresses the following questions: 1) What is the role of landscape context in shaping the diversity of citrus pests and their natural enemies? 2) What impact does landscape context have on shaping the diversity of ground-dwelling predatory arthropods?

To answer the above questions, a transect will be established across the citrus orchard with five sampling points extending to the adjacent remnant vegetation. In each sampling point, five major citrus pests (False codling moth (FCM), Fruit flies, Citrus thrips, California red scale, and seven mealybug species associated with citrus) and their natural enemies will be sampled using recommended pest monitoring traps, visual monitoring, and pitfall traps. The outcomes of this study will enable the southern African citrus industry to plan new sustainable citrus farms and rehabilitate the existing citrus farms to achieve improved conservation biological control.

Evaluation of potential repellents for false codling moth, *Thaumatotibia leucotreta* (Meyrick)

RESEARCH TEAM
Dr Candice Coombes, Prof. Martin Hill and Prof. Sean Moore

STUDENT
Sifundo Ngxekisa (MSc)

The management of false codling moth (FCM), given its status as a quarantine pest, is important for the South African citrus industry. This management involves a variety of pre-harvest control techniques, including the use of semiochemicals. Semiochemicals are organic compounds that convey chemical messages between individuals which induce behavioural or physiological changes.

Semiochemical pest management strategies, such as insect repellents derived from natural sources, are preferred over other techniques because they are host-specific, residue-free, and less toxic. This renders them safe for the environment and humans. Although there has been extensive research on the use of insect repellents in integrated pest management (IPM) programmes, much of this research has been focused on pest species of medical and veterinary importance; thus, there is scope to increase the use of repellents against insect pests of agricultural importance. Recently, the deterrent effects of several plant extracts, essential oils, insecticides and a fruit extract (mango) on reducing FCM oviposition on oranges under laboratory conditions have been investigated. Eight compounds were identified as having significant deterrent effects: two essential oils (lavender and peppermint), two crude plant extracts (garlic and marigold), three chemicals (Delegate, Coragen, and Warlock), and mango extract.

MSc student, Sifundo Ngxekisa, has since continued this research, establishing the nature of these deterrents (true repellents or odour maskers), the effect that emitted fruit volatiles have on the efficacy of these compounds, and the possibility of incorporating these repellents in a push-pull system for the management of FCM. No-choice and choice experiments using artificial oranges have confirmed that these compounds may be considered true repellents (compounds that cause an oriented movement away from the source), with the crude extracts, mango, marigold and garlic exhibiting the greatest repellent effect in reducing oviposition on treated artificial oranges. Preliminary results suggest that when gravid females are given the option to oviposit on field-collected oranges or artificial oranges treated with the same compound, at the same concentration, a preference for field-collected oranges was observed. This suggests that the volatiles emitted by the field-collected fruit, which serve as oviposition attractants to FCM, may reduce the efficacy of these repellents under more natural conditions. Higher application doses may, therefore, be required to counteract this effect. The use of these repellents in push-pull systems is currently being investigated, with several potential FCM attractants being tested, including cypress oil, sage oil, and capsicum.

Effect of netting on Cryptophlebia leucotreta granulovirus for the management of false codling moth

RESEARCH TEAM
Dr Michael Jukes, Dr Candice Coombes, Prof. Martin Hill and Prof. Sean Moore

STUDENT
Kurhula Luphondo (MSc)

Citrus is a major component of South Africa's fruit production and export, significantly contributing to foreign exchange revenue. Consequently, extensive research focuses on developing techniques to enhance fruit yield while reducing costs and environmental impacts. However, the citrus industry faces challenges, particularly the infestation of pests like the false codling moth (FCM), which is native to sub-Saharan Africa and poses a serious threat to exports due to strict no-tolerance policies for larvae in shipments.

To combat this, Cryptophlebia leucotreta granulovirus-SA (CrleGV-SA), a commercial biopesticide, is one of the control measures available for suppressing FCM populations in the field. The virus is, however, sensitive to ultraviolet (UV) radiation from the sun. Shade netting is used in citrus orchards in South Africa as a buffer against temperature extremes, hail, sunburn, and wind. However, there is limited literature on the effects of netting, and the impact of shade netting on baculoviruses remains unknown. The identification of a positive impact of netting on CrleGV-SA's lifespan or persistence could be important as shade nets can be included in more citrus orchards for the control of many pests, including FCM.

Figure 90. Netted cage and non-netted structures where the semi-field exposure of CrleGV-SA was conducted. Chicken wire was placed on top of the galvanised table to prevent birds and small mammals from interfering with the experiments. Photos: Kurhula Luphondo.

Figure 91. Kurhula Luphondo spraying fruit with CrleGV-SA. Photo: Michael Githae.

This study explored the effects of shade netting on CrleGV-SA, focussing on semi-field exposure of the virus under netted and non-netted structures using virus-treated fruit. After natural UV exposure for 1, 7, 14, and 21 days, the applied virus was washed from the fruit and surface-dose bioassays were performed to assess and determine the virulence and persistence of CrleGV-SA under netting. Preliminary results showed that netting provides little protection to CrleGV-SA from UV exposure. It was noted that the virus degraded quickly and lost activity after day 1 of natural UV exposure. As a result, another experiment was conducted, in which treated fruit were evaluated across shortened time periods of 1, 3, 5, and 7 days post-natural UV exposure. Surface biological assays are underway to assess and determine the virulence and persistence of CrleGV-SA under netting and, as such, draw a more informed conclusion as to the level of UV protection offered for CrleGV-SA by netted orchards.

Evaluating effects of *Cryptophlebia peltastica* nucleopolyhedrovirus and *Cydia pomonella* granulovirus mixtures against *Thaumatotibia leucotreta*

RESEARCH TEAM
Dr Michael Jukes, Prof. Martin Hill, Prof. Sean Moore, and Prof. Caroline Knox,

STUDENT
Keith Kambani (MSc)

Agricultural pests cost the South African citrus industry millions of Rands annually. *Thaumatotibia leucotreta* and *Cydia pomonella* are two such pests greatly affecting crop exports. Baculoviruses have been harnessed as biological pesticides for the control of these pests, becoming important players in Integrated Pest Management (IPM) programmes. *Cryptophlebia peltastica* nucleopolyhedrovirus (CrpeNPV) and *Cydia pomonella* granulovirus (CpGV) are two such baculoviruses. Products containing these viruses are currently being used in South Africa, and CpGV is already being used in Europe, with CrpeNPV also soon to be commercialised. Thus, likelihood of the two baculoviruses encountering one another has significantly increased. This encounter will be brought about through the application of these biopesticide products within the same field, either simultaneously or at different time intervals, and it is important to decipher whether synergistic effects will be observed when the two viruses encounter one another. This study focuses on evaluating the interactions of CrpeNPV and CpGV during infection of *T. leucotreta*. The CrpeNPV virus stock was obtained through propagation in 2nd and 3rd instar *T. leucotreta* larvae, while CpGV virus stocks were obtained from River Bioscience (South Africa). Preliminary DNA screening, involving PCR with genome specific primers, was conducted to confirm the identity of each virus isolate. Surface dose biological assays with CrpeNPV showed increased infectivity with rising concentration. Single infections with CpGV are currently underway with mixed infections expected to be carried out according to the project timeline. Delayed ingestion evaluations will also be carried out to understand the effect of delayed ingestion of each virus on overall infectivity. Lastly, DNA analyses, involving sequencing and BLAST analysis will be used to confirm the cause of mortality within the host.

The expression and evaluation of *Trichoplusia ni* granulovirus (TnGV) enhancin for potential application as an additive for improved efficacy of baculovirus-based biopesticides

RESEARCH TEAM
Dr Michael Jukes, Prof. Caroline Knox, Prof. Martin Hill and Prof. Sean Moore

STUDENT
Siyabonga Phoswa (MSc)

The IPM programme to control *T. leucotreta* using *Cryptophlebia leucotreta* granulovirus-SA (CrleGV-SA) as a biopesticide has been successful for a long time in South Africa. However, due to several limitations associated with CrleGV-SA application, recent updates in EU regulations, and general challenges with baculovirus biopesticides, finding novel ways to enhance infectivity for improved *T. leucotreta* control is of interest. Various laboratory bioassay studies have shown that dual infection of baculoviruses in *T. leucotreta* decreases the amount of virus required to cause mortality but prolongs the lethal time. This suggests that mixed infections may not be ideal owing to potential competition for host resources. The use of infectivity proteins to enhance virus pathogenicity has long been considered promising and has gained traction over recent years.

Studies have shown that viral enhancin genes can significantly increase viral potency and pathogenicity in various insect hosts. For example, LdMNPV, AcMNPV, and TnGV strains engineered to express enhancin genes demonstrated 2- to 4-fold increases in potency compared to wild-type viruses, with faster time-to-kill (LT_{50}) and increased toxicity in bioassays across multiple insect species. This study focuses on expressing a TnGV enhancin protein in a yeast-based system and evaluating its effectiveness in protein-virus infectivity against *T. leucotreta.* The enhancin protein will be used in conjunction with CrleGV, and surface dose biological assays will assess the lethal concentration and lethal time of virus only versus protein-virus infections. The enhancin protein may promote increased baculovirus transport over the midgut leading to more host cell infections, thereby improving CrleGV infectivity.

The efficacy of the parasitoid wasp, *Trichogrammatoidea cryptophlebiae* (Nagaraja) against a range of economically important Tortricid pests in South Africa.

RESEARCH TEAM
Prof. Martin Hill, Prof. Sean Moore and Dr Megan Mulcahy

STUDENT
Emma Stirk (MSc)

This MSc research focuses on *Trichogrammatoidea cryptophlebiae*, an egg parasitoid endemic to South Africa, with the goal of advancing its mass-rearing potential for biological control in South African agriculture. *Trichogrammatoidea cryptophlebiae* holds promise as a sustainable pest management solution across various crops. However, critical knowledge gaps remain regarding its biology, particularly factors influencing its fitness, fertility, and field efficacy in crops other than citrus.

The study specifically examines the parasitoid's effectiveness against key pests, including the Litchi Moth (*Cryptophlebia peltastica*), Codling Moth (*Cydia pomonella*), Macadamia Nut Borer (*Thaumatotibia batrachopa*), *Lobesia vanillana*, and False Codling Moth (*Thaumatotibia leucotreta*). Owing to low pest pressure in certain crops (apples, litchis, and wine grapes), these trials were discontinued moving into the second season, and the research has shifted its focus solely to

macadamias. Trial sites have been established in all major macadamia-growing regions of the country to allow for comparison across the various areas. Initial observations show parasitism activity in macadamias, but chemical pesticide use has compromised the results from the first season.

To address this, a series of non-target bioassays will evaluate the effects of pesticide residues on the pre-imaginal and adult stages of the parasitoid. These insights aim to inform spray programmes that integrate *T. cryptophlebiae* into pest management systems.

In the laboratory, several key experiments have been completed, including fertility, haplodiploidy confirmation, flight capacity, no-choice and choice tests, competition assays, and sex ratio analyses. Preliminary findings have extended the known host range of *T. cryptophlebiae* to include Litchi Moth and *Lobesia vanillana*, confirmed its haplodiploidy as expected, and provided valuable insights into sex allocation strategies throughout its lifespan.

Statistical analysis of these trials is underway and is expected to yield further critical insights into the parasitoid's biology that can help advise mass-rearing systems. These findings have the potential to significantly enhance our understanding of *T. cryptophlebiae* and its role in sustainable agriculture.

Figure 92. Emma releasing *Trichogrammatoidea cryptophl*ebiae in macadamia orchards in the Eastern Cape. Photo: Conor Thompson.

Figure 93. Female Trichogrammatoidea cryptophlebiae. Photo: Emma Stirk.

Bioprospecting for entomopathogenic fungi against foliar citrus pests

RESEARCH TEAM
Dr Candice Coombes, Prof. Martin Hill and Prof. Sean Moore

STUDENT
Erin Boon (MSc)

Entomopathogenic fungi (EPF) have been shown to play important roles in the management of insect pest populations under natural conditions. Previous research has shown that several isolates are effective at managing the soil-dwelling life stages of false codling moth (FCM). However, against foliar citrus pests, the same isolates that performed well under laboratory conditions, performed poorly under field conditions. This was attributed, most likely, to UV radiation. As these isolates were obtained from the soil environment, it stands to reason that EPF isolated from the foliar environment may be more suited for foliar application and, thus, management of foliar pests. Bioprospecting for these EPF was thus initiated. In addition, EPF may exist as endophytes within plant parts, for example, leaves, roots and stems.

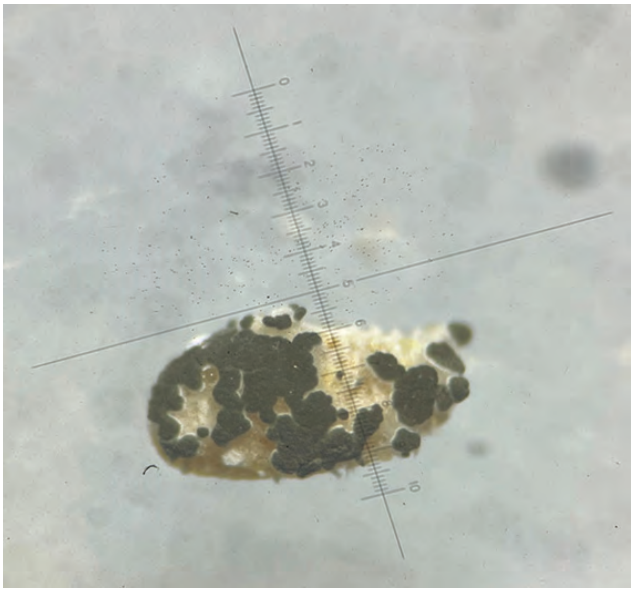

Figure 94. Adult female citrus mealybug displaying signs of mycosis as a result of *Metarhizium* infection. Photo: Erin Boon.

Endophytes are described as fungi or bacteria that exist within the plant tissue without causing harm to the host. Thus, bimonthly bioprospecting of plant material was conducted in three conventional and three organic citrus orchards in the Sundays River Valley, Eastern Cape. Only one potential entomopathogenic endophytic isolate out of 504 leaf samples was recovered, with a further six potential EPF isolates recovered from infected foliar pests associated with agricultural fields.

Subsequently, the seven isolates were morphologically identified to genus level: 1 yeast* (included as it passaged through FCM), 4 *Beauveria* (1 endophyte), 1 *Fusarium,* and 1 *Metarhizium.* The pathogenicity (screening) of the seven novel isolates toward adult female citrus mealybug, a foliar citrus pest, was evaluated under laboratory conditions for which the average mortality ranged from 15% to 90% when applied at a concentration of 1×10^7 conidia/ml. The five top-performing isolates underwent dose-response bioassays and were further investigated for UV tolerance. The two best-performing isolates demonstrated a UV tolerance of over 67 % relative germination after 1 h exposure to Xenon lamps (300-800 nm) at 0.3 $W/m^{2,}$ 48 h post incubation.

POLYPHAGOUS SHOT HOLE BORER

RESEARCH TEAM
Prof. Brett Hurley (FABI, University of Pretoria), Prof. Martin Hill and Dr. Francois Roets (Stellenbosch University)

STUDENT
Garyn Townsend (PhD, UP)

COLLABORATORS
FABI, Vietnamese Academy of Forest Sciences (VAFS)

The polyphagous shot hole borer or PSHB (*Euwallacea fornicatus*is) is a highly invasive tree pest in various countries and is now established in eight of the nine provinces of South Africa, making it the largest outbreak of this beetle worldwide. Female PSHB beetles locate host trees, bore into them, and release a symbiotic fungus, *Fusarium euwallacea*. This pathogenic fungus can cause a disease known as Fusarium dieback which, in many cases, kills the attacked tree. The impacts of PSHB in South Africa are still primarily seen in urban forests where it preferentially attacks non-indigenous, ornamental trees. To date, the beetle has been recorded attacking 162 tree species in South Africa alone. Monitoring projects in indigenous forests showed a consistent increase in the number of infested trees over five years. The PSHB has been recorded attacking 78 native species, 42 of which are potential reproductive hosts. This beetle may be a threat to indigenous forests, not only in South Africa but throughout the continent, and continued monitoring of this beetle's spread and impacts is imperative. Various projects investigating the impacts of PSHB and its fungus in botanical gardens, commercial plantations and on agricultural crops such as avocado, macadamia, pecans and deciduous fruits in South Africa are also ongoing.

Garyn Townsend's PhD, based at the Forestry and Agricultural Biotechnology Institute (FABI), focuses on monitoring the impacts of PSHB in native forests and investigating the potential for biological control of the beetle and/or its fungus. Two scouting trips to Vietnam, where the beetle is native, took place in April 2023 and March 2024 in collaboration with the Vietnamese Academy of Forest Sciences. Over 400 kgs of PSHB infested material was brought back to South Africa and all emerging insects were collected to identify and characterize any potential natural enemies of PSHB. Various wasp species were collected, but rearing trials on PSHB colonies failed. Collections of bark and ambrosia beetle parasitoids in South Africa were also performed with 16 different species of scolytine parasitoids being collected. At least one of these species, *Heterospilus* sp., emerged from PSHB infested wood and may be using PSHB as a host. Genetic tools are being employed to determine if there is an association between this wasp and PSHB. Other parasitoid wasp species discovered in Taiwan have also been shown to attack PSHB, but the impact of these on beetle populations is still being tested. An entomopathogenic nematode has also recently been discovered inhabiting PSHB galleries in Japan, and rearing trials will soon take place to determine if it can attack PSHB.

Figure 95. Garyn and members of the Vietnamese Academy of Forest Science (VAFS) sampling a PSHB infested *Acacia mangium* tree.

All work on this pest is being done in collaboration with nine institutions throughout South Africa, as well as overseas universities and government organisations, forming a research network that is taking an holistic approach to understanding this pest which poses a significant threat to agricultural crops, urban and native forests throughout the world. The PSHB has been introduced into seven countries, showing how easily it can travel between nations, emphasising the importance of collaborative research. Control of PSHB will be difficult and will likely require an integrated approach, using biological control agents, susceptible tree removal, and the planting of less susceptible tree species.

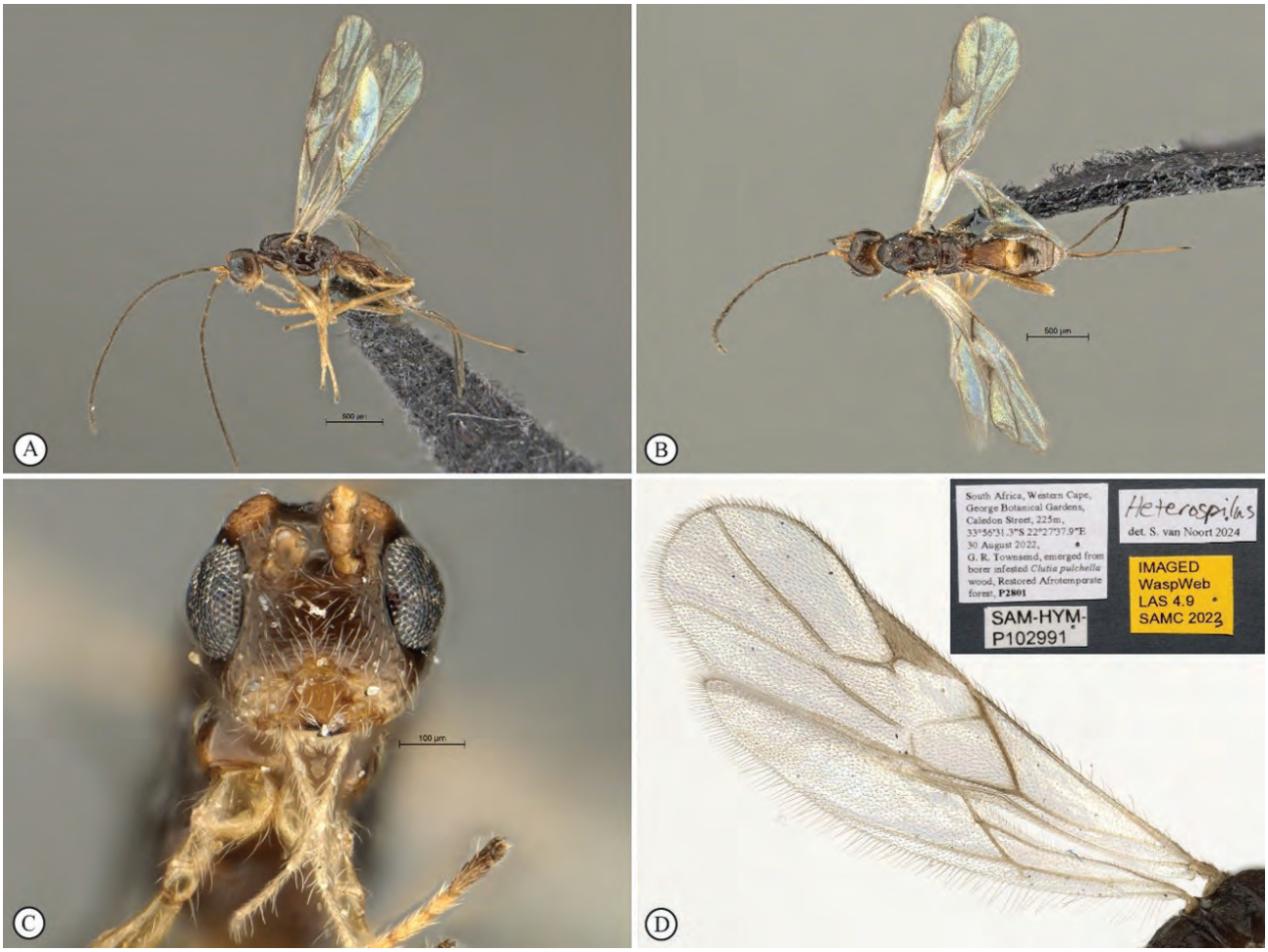

Figure 96. *A Heterospilus* sp. parasitoid that emerged from PSHB infested wood collected in George Botanical gardens. (A) habitus, lateral view. (B) habitus, dorsal view. (C) head, anterior view. (D) wings, dorsal view.

COMMUNITY ENGAGEMENT

Community engagement is an integral part of the work that the CBC does. Engagement with communities around South Africa about the topics of invasive alien species and biological control happens through in-person interactions or through the media and social media. It is important for people to know about invasive species, and that there is a sustainable control option which should be integrated into their management plans. Our team also interacts with school learners, when the opportunities are made available, to teach them about the field of entomology and applied entomology. Below we highlight some of our 2024 activities.

Waterweed Engagement

The CBC continued to show support and guidance with various stakeholders around different invaded water systems. Julie Coetzee and Kelby English drove many different training sessions and workshops with community partners. As a result, the number of community partners expanded, with several more groups attending informational sessions to learn about biocontrol opportunities for future implementation. The CBC regularly participates in monthly to quarterly meetings for different systems, playing a crucial role as advisers on effective waterweed management practices.

Figure 97. Madie Mbayela (MSc Wits), Dr Nompumulelo Baso (NRF SAIAB & RU CBC), and Dr Kelby English (RU CBC) manning the Centre For Biological Control information/display table at the Stonehaven Flotilla event held on 7 September 2024 along the Vaal River. On display were invasive water lettuce, giant salvinia and water hyacinth plants with their related biocontrol agents.

Figure 98. (A) Prof. Julie Coetzee highlighted the threat of water lettuce and water hyacinth to the Vaal River, at a ministerial, seen here with Gauteng Premier, Andrek Panyaza Lesufi (B).

Table 3. Rearing station partners

Hartbeespoort Dam	Bronkhorstspruit Dam	Benoni Lakes	Vaalkop Dam
The Coves	Aquavista Mountain Estate	Benoni Lake Club	Bushwillow Estate
Estate D'Afrique	Bajadam resort	Facility Service Group (FSG) – Lakeside Mall	Mziki Safari Lodge
Hartbeespoort Boating Club (HBK)	Bonamanzi Resort and Marina		Finfoot Lake Reserve
Harties Boat Company	Bronkhorstspruit Catchment Management Forum		
Ifafi Adventure Academy	The Catamaran Club		
Ifafi Senior Club	Clover Hill Club		
Kosmos Marina	Oudezwaanskraal		
Lakeland Estate	Summer Place		
Leloko Lifestyle Estate			
Pecanwood Estate			
Blesbokspruit Wetland Reserve	**Vaal River**	**Other**	
Blesbokspruti Research Centre	Community members	Bonnievale Community	
	Rand Water	City of Cape Town	
		Ezemvelo KZN Wildlife?	
		uMngeni-uThukela Water	

Community engagement highlights included giving talks at Ministerials, on the Vaal River; and on the Mokolo River where giant salvinia is a major issue. We also gave a talk to officials from the Govan Mbeki Municipality in Secunda, where water hyacinth has invaded water bodies in the area. We then released *Megamelus scutellaris* with the officials, and continue to engage with them. The CBC will continue to engage with communities who assist in implementing biological control as part of the management plans. We would like to thank all our partners around the country for fighting this fight with us!

Figure 99. Mikki Roxmouth (SALI Gauteng Chairperson, left) with guest speaker, Dr Kelby English (CBC, centre), and Francois Le Roux (FSG, right). Photo: Kay Montgomery, at the South African Landscapers Institute AGM.

Figure 100. Wally, the water lettuce weevil, attracted visitors to the CBC's biocontrol display at the opening of the Vaal River in September, 2024.

Figure 101. Wandisile Mdiza looking for *Megamelus scutellaris* establishment in Secunda, before releasing the hoppers for water hyacinth control. Photo: Julie Coetzee.

Figure 102. Waterweed biocontrol training day with Joburg City Parks and Zoo, hosted at the Rand Water biocontrol agent mass-rearing facility, led by Dr Kelby English of the CBC and Dr Leslie Hoy of RW. Photo: Wayne Borton.

Neltuma engagement

An earlier section in this Annual Report covers the Centre for Biological Control's co-ordination of work on *Neltuma* (previously *Prosopis* section *Algarobia*), but this section highlights the community engagement activities. Efforts to engage irrigation farming enterprises and Northern Cape communities in management of *Neltuma* need further funding to progress. We have sown the ideas, but more work is required for these to bear fruit. Unfortunately, staff turnover in critical positions in stakeholder organisations has meant lack of continuity with the irrigation farmers, and costs of management remain an issue.

Our work on *Neltumia* led directly to partnerships with Sol Plaatje University and with the National Centre for Vegetation Cover Development and Combating Desertification of the Kingdom of Saudi Arabia (through Tilad Environmental). The relationship with Sol Plaatje led to the co-hosting of the National Symposium on Biological Invasions in September 2025 and the development of an idea for a Centre that looks at biomass use in agriculture. The work with the Kingdom of Saudi Arabia might well lead to investment into cactus and *Neltuma* biological control.

Figure 103. The delegation from the Kingdom of Saudi Arabia at the rearing facility in Upington receiving a demonstration from Blair Cowie. Photo: Philip Ivey.

With funding through the JRS Biodiversity Foundation, we have worked with Sol Plaatje University on the Global Environmental Facility 7-funded project, which investigates restoring sustainable livelihoods in arid areas. Management of *Neltuma* is a critical part of habitat and grazing restoration. The JRS Biodiversity Foundation project has enabled us to collaborate with SANParks and authorities in Namibia and Botswana to improve *Neltuma* management across three countries.

Late in 2024, our work with landowners on the Orange River west of Augrabies Falls led to a very generous donation towards the Upington mass-rearing facility that focuses on *Neltuma* and cactus biological control. The work in this region of the Orange River will also link to biomass projects that we are investigating with solar-power generators in this region.

We continue to nurture relationships with agriculture, government, mining companies and solar-energy generators across the Northern Cape in an effort to manage *Neltuma* in an integrated fashion using both biological control and biomass utilization as tools to reduce the spread and impact of this species. The paper by Ivey et al. (2024), prepared and published with funding from the National Research Foundation, illustrates the collaboration of all stakeholders in dealing with this complex problem.

School Engagement

The Science Internship Programme is still going strong, this programme exposes learners to different departments within the Science Faculty at Rhodes University. School learners are selected for the programme through GADRA, an education NGO based in Makhanda. In 2024, we welcomed 23 Grade 10 and 11 learners to Rhodes University. The CBC coordinates this programme and the learners are exposed to our research and facilities along with other departments who have joined.

Partners in the CBCs community engagement activities

Agri SA, U3A Grahamstown, Red Meat Research and Development South Africa, Grahamstown Horticultural Society, Eastern Cape Game Management Association, Wildlife Ranching South Africa EC, Professional Hunters Association of South Africa EC, SANParks, Addo Elephant National Park, Camdeboo National Park, Thomas Baines Nature Reserve, Sibuya Game Reserve, Wool Growers Association, Red Meat Producers Roadshow, The Coves, Lakland, Leloko, Harties Harbour, Harties HBK, Kosmos, Ifafi Senior Club, Estate DÁfrique, Pecanwood, Umgeni Water, Ezemvelo KZN Wildlife, City of Cape Town.

Schools: Ntsika Secondary School, Nombulelo Secondary School, Khutliso Daniels School, Victoria Girls High School, Graeme College.

Funders

The CBC would like to acknowledge the various funders for 2024:

National Funders
Citrus Research International (CRI)
Research for Citrus Export (RCE) Sector Innovation Fund of the Department of Science and Technology (DST)
National Research Foundation (NRF)
Department of Science and Technology – National Research Foundation - The South African Research Chairs Initiative (DST-NRF SARChI)
Red Meat Research and Development South Africa
River BioScience
Drakenstein Trust
South African Water Research Commission (WRC)
Rand Water

International Funders
AgriFutures Australia
Australian Government Department of Agriculture and Water Resources (Rural R&D for Profit programme)
Biosecurity South Australia (Prima Industries and Regions, South Australia)
Shire of Ravensthorpe, Western Australia
Queensland Department of Agriculture, Australia
New South Wales Department of Primary Industry; Australia
Manaaki Whenua –LandCare Research, New Zealand

Research Outputs

Graduates

PhD

Baso, Nompumelelo Catherine, MSc (Rhodes), in Botany, in the Department of Botany. Degree by thesis. Thesis: The Enemy Release Hypothesis and beyond: Lagarosiphon major invasion dynamics and management options for New Zealand using native natural enemies from South Africa. Supervisor: Professor JA Coetzee.

De Beer, Ernst Friedrich Ludwig, MSc (NWU), in Entomology, in the Department of Zoology and Entomology. Degree by thesis. Thesis: Augmentation of *Aphytis melinus* DeBach Hymenoptera: Aphelinidae) for the control of California red scale *Aonidiella aurantii* Maskell (Hemiptera: Diaspididae) on citrus. Supervisor: Distinguished Professor MP Hill. Co-supervisor: Professor S Moore.

Wolmarans, Abigail, MSc (NWU), in Entomology, in the Department of Zoology and Entomology. Degree by thesis. Thesis: Developing biological control agents for the management of the invasive tree *Robinia pseudoacacia*. Supervisor: Dr GD Martin. Co-supervisor: Dr P Weyl (CABI).

Griffith, Tamzin Camilla, MSc (Rhodes), in Entomology, in the Department of Zoology and Entomology. Degree by thesis. Thesis: Biological control of torch cactus in South Africa: Finding a suitable agent for a weed with an unknown indigenous distribution. Supervisor: Professor ID Paterson.

Mushore, Tapiwa Gift, BSc Hons (Zimbabwe), MSc (Rhodes), in Entomology, in the Department of Zoology and Entomology. Degree by thesis. Thesis: Biology and management of the fruit piercing moth *Serrodes partita* in citrus orchards. Supervisor: Distinguished Professor MP Hill. Co-supervisors: Dr C Coombes and Professor S Moore (CRI).

MSc

Mommsen, Wayne Trevor, BSc (RAU), BSc Hons (UJ), in Entomology, in the Department of Zoology and Entomology. Degree by thesis. Thesis: Managing releases of Anagyrus vladimiri (Triapitsyn) to augment biocontrol of the citrus mealybug *Planococcus citri* (Risso) in South African citrus orchards. Supervisor: Distinguished Professor MP Hill. Co-supervisor: Professor S Moore (CRI).

Van Staden, Gretha, BSc Hons (NWU), in Entomology, in the Department of Zoology and Entomology. Degree by thesis. Thesis: Developing a community of practice to promote the use of biological control in the integrated management of *Prosopis* in South Africa. Supervisor: Distinguished Professor MP Hill. Co-supervisors: Ms K Weaver and Mr P Ivey.

Chikodza, Tressia, BSc (WSU), BSc Hons (Rhodes), in Botany, with distinction, in the Department of Botany. Degree by thesis. Thesis: The effect of biological control on the population dynamics of *Pontederia crassipes* Mart. (Pontederiaceae) and *Salvinia minima* Baker (Salviniales: Salviniaceae). Supervisor: Professor JA Coetzee.

Moagi, Raynold, BSc Agric (UMP), in Entomology, with distinction, in the Department of Zoology and Entomology. Degree by thesis. Thesis: An assessment of the status of *psylloid* species (Hemiptera: Psylloidea) as potential pests of commercial citrus in southern Africa: Implications for pest management. Supervisor: Distinguished Professor MP Hill. Co-supervisors: Dr E Mauda and Mr L Mukwevho.

Muleya, Naho, BSc Hons (Venda), in Microbiology, with distinction, in the Department of Biochemistry, Microbiology & Bioinformatics. Degree by thesis. Thesis: The expression and evaluation of CrpeNPV gp37 as a formulation additive for enhanced 19 infectivity with CrleGV-SA and improved *Thaumatotibia leucotreta* control. Supervisor: Professor C Knox. Co-supervisors: Distinguished Professor MP Hill and Dr M Jukes.

Tole, Siviwe, BSc Hons (UP), in Microbiology, in the Department of Biochemistry, Microbiology & Bioinformatics. Degree by thesis. Thesis: Evaluating baculovirus mixtures against false codling moth *Thaumatotibia leucotreta* Meyrick. (Lepidoptera: Tortricidae). Supervisor: Professor C Knox. Co-supervisors: Distinguished Professor MP Hill and Dr M Jukes.

Peer-reviewed articles

Righetti, T., de la Fuente, D., Paper, M. K., Brentassi, M. E., Hill, M. P., Coetzee, J. A., ... and Sosa, A. J. (2024). Effects of elevated CO_2 on the water hyacinth-biocontrol agent *Megamelus scutellaris* (Hemiptera: Delphacidae) and its yeast-like symbiotes. *Biological Control*, *188*, 105433.

Moore, S. D., Ehlers, R. U., Manrakhan, A., Gilbert, M., Kirkman, W., Daneel, J. H., ... and Malan, A. P. (2024). Field-scale efficacy of entomopathogenic nematodes to control false codling moth, *Thaumatotibia leucotreta* (Lepidoptera: Tortricidae), in citrus orchards in South Africa. *Crop Protection*, 106610.

Paterson, I. D., Motitsoe, S. N., Coetzee, J. A., and Hill, M. P. (2024). Recent post-release evaluations of weed biocontrol programmes in South Africa: A summary of what has been achieved and what can be improved. *BioControl* 69:279–291.

Marsberg, T., Peyper, M., Kirkman, W., Moore, S. D. and Sutton, G. (2024). The effect of permanent protective netting on insect pest prevalence in citrus orchards in South Africa. *African Entomology*, *32*, 1–9.

Sandenbergh, E., Petruzzella, A., and Coetzee, J. A. (2024). Distribution and sexual reproductive potential of *Iris pseudacorus* L. (Iridaceae) in South Africa. *South African Journal of Botany*, *167*, 31–39.

Yell, L. D., Sutton, G.F., van Steenderen, C.J.M., Canavan, K., McConnachie, A.J. and Paterson, I.D. (2024). Field-based surveys and laboratory tests indicate that candidate biocontrol agents for African lovegrass from South Africa are not suitable for release in Australia. *Biocontrol Science and Technology*, 34(2): 203–2024.

Townsend, G., van Rooyen, E., Hill, M., De Beer, W., and Roets, F. (2024). Invasion of an Afrotemperate forest complex by the polyphagous shot hole borer beetle. *Entomologia Experimentalis et Applicata*.

Medzihorský, V., Mally, R., Trombik, J., Turčáni, M., Medzihorská, M., Shoda-Kagaya, E., Martin, G.D., Sopow, S., Kochi, K. and Liebhold, A.M. (2024). The demise of enemy release associated with the invasion of specialist folivores on an invasive tree. *Ecography* e07082.

Moffat, R., van Noort, S., Coetzee, J., and Hill, M. (2024). Biotic resistance towards *Hydrellia egeriae*, a biological control agent for the aquatic weed *Egeria densa*, in South Africa. *African Entomology*, *32*.

van Valkenburg, J. L. C. H., Beyer, J., Champion, P., Coetzee, J., Diadema, K., Kritzinger-Klopper, S., ... and Schönberger, I. (2024). Naturalised Hakea. What species are we actually talking about in Europe?. *Botany Letters*, 1–14.

Aigbedion-Atalor, P., Upfold, J., Coombes, C., Moore, S. and Hill, M. (2024). Sexual selection in *Thaumatotibia leucotreta* (Meyrick) is shaped by contrasting geographic adaptations, but does it matter for area-wide sex pheromone control tools? *Ann Appl Biol*. 2024, 1–11.

Coombes, C., Hilliar, S., Moore, S., and Hill, M. (2024). The addition of molasses to the *Cryptophlebia leucotreta* granulovirus formulation improves its efficacy against *Thaumatotibia leucotreta* Meyrick (Lepidoptera: Tortricidae), a pest of citrus in South Africa. *African Entomology*, *32*.

Schneider, S. C., Coetzee, J. A., Galvanese, E. F., Harpenslager, S. F., Hilt, S., Immerzeel, B., Kohler, J., Misteli, B., Motitsoe, S. N., Padial, A.A., Petruzzella, A., Schechner, A., Thiebaut, G., Thiemer, K. and Vermaat, J. E. (2024). Causes of macrophyte mass development and management recommendations. *Science of The Total Environment* 931: 172960.

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Moffat, R., Weaver, K., Ngxande-Koza, S., Sebola, K., English, K., Kinsler, D., and Coetzee, J. (2024). Bridging boundaries: Six years of community engagement with biological control implementation and monitoring of water hyacinth on Hartbeespoort Dam, South Africa. *Biological Control*, 105544.

Baso, N. C., Bownes, A., Paynter, Q., Arnaud, C., Hill, M., and Coetzee, A. J. (2024). Biogeographical comparison of *Lagarosiphon major* between native South Africa and invaded New Zealand: A natural enemy release case study? *Biological Control*, 105584.

Reid, M. K., Coetzee, J. A., Gettys, L. A. and Hill, M. P. (2024) The importance of multigeneration host specificity testing: rejection of a potential biocontrol agent of *Nymphaea mexicana* (Nymphaeaceae) in South Africa. *Florida Entomologist* 107(1).

van Steenderen, C. J., and Sutton, G. F. (2024). Climate covariate selection influences MaxEnt model predictions and predictive accuracy under current and future climates. *Ecological Modelling*, *498*, 110872.

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Muskett, P., Sutton, G. F., and Paterson, I. D. (2024). Long-term post-release evaluation shows *Hypogeococcus* sp. is an effective biological control agent for queen of the night cactus in South Africa. *Biocontrol Science and Technology*, *34*(10), 915–920.

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Sieben, E.J.J., Steenhuise,n S-L., Vidal, J.D., Martin, G.D. and le Roux, P.C. (2024). Modelling

landscape-scale occurrences of common grassland species in a topographically complex mountainous environment. *Plant Ecology*,1–14.

Chikowore, G., Weyl, P.S. and Martin, G.D. (2024). First record of *Robinia hispida* L.(Fabaceae) in South Africa. *Biological Invasions*, 1–7.

Hinz, H.L., Cabrera Walsh, G., Paterson, I., Paynter, Q., Schwarzlander, M., Smith, M. and Weyl, P. (2024). Enhancing pre-release studies for weed biocontrol agents: A review of existing and emerging tools. *Biological Control* 198: 105607.

Reid, M.K., Sutton, G.F., Coetzee, J.A., Gettys L.A. and Hill, M.P. (2024). Distribution and host preference of a potential biocontrol agent with a new association for the alien water lily *Nymphaea mexicana* in South Africa. *African Journal of Aquatic Science, 49*:2, 132–144.

van Steenderen, C.J.M., Mauda, E.V., Kirkman, W., Faulkner, K.T. and Sutton, G.F. (2024). The Asian Citrus Psyllid (*Diaphorina citri*) in Africa: using MaxEnt to predict current and future climatic suitability, with a focus on potential invasion routes. *African Entomology* 32.

Herbert, L., Zanga, A., Kinsler, D., Ayala, V., Kamla, A. T., and Diaz, R. (2024). Optimizing aquatic weed management in Lake Ossa, Cameroon: Harnessing the power of biological control and real-time satellite monitoring. *Biological Control*, 105650.

Mangan, R., Gareeb, M., Boeno, M., da Silva, C. G., Cowie, B., Teles, A. M., ... and Zachariades, C. (2024). Risk assessment of the laboratory host range and a molecular characterisation determining the field host range of *Lixus aemulus*, for the biological control of *Chromolaena odorata* in South Africa. *Biological Control*, *197*, 105591.

Wood, K. A., Jupe, L. L., Aguiar, F. C., Collins, A. M., Davidson, S. J., Kirkpatrick L., Magalhães T.L., McKinley E., Nuno A., Pagès J.F., Petruzzella A., Pritchard D., Reeves J.P., Thomaz S.M., Thornton S.A., Walton-Freeman W., Yamashita H. and Newth, J. L. (2024). A global systematic review of the cultural ecosystem services provided by wetlands. *Ecosystem Services*, *70*, 101673.

Vermaat, J.E., Thiemer, K., Immerzeel, B., Schneider, S.C., Sebola, K., Coetzee, J.A., Petruzzella, A., Motitsoe, S.N., Baldo, M., Misteli, B., Thiebaut, G., Hilt, S., Köhler, J. and Harpenslager, S.F. (2024). Does perceived nuisance abundance of water plants match with willingness-to-pay for removal? Contrasts among different user categories. *Environmental Management*, 1–13.

Mnqeta, Z. and Paterson, I. D. (2024). Biological control against *Opuntia aurantiaca* Lindley (Cactaceae) and the perceptions of land-users in the Eastern Cape Province of South Africa. *Biocontrol Science and Technology*, 1–13.

Vermaat, J.E., Thiemer, K., Immerzeel, B., Schneider, S.C., Sebola, K., Coetzee, J.A., Petruzzella, A., Motitsoe, S.N., Baldo, M., Misteli, B., Thiebaut, G., Hilt, S., Köhler, J. and Harpenslager, S.F. (2024). Mass development of aquatic plants: Effects of contrasting management scenarios on a suite of ecosystem services. *Journal of Applied Ecology* 61:76–89.

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Clark, V.R. and Martin, G.D. (2024). Risks and vulnerabilities to and from Africa's major mountain ranges (Africa-Introduction). In *Safeguarding Mountain Social-Ecological Systems, Vol 2* (pp. 65–72). Elsevier.

Clark, V.R., Ah-Peng, C., Arévalo, J.R., Backes, A.R., Haider, S., Rouget, M., Martin G.D. (2024). Africa's Mountainous Islands: Archipelagos of fire, water, and problem species. In *Safeguarding Mountain Social-Ecological Systems, Vol 2* (pp. 97–107). Elsevier.

Bergallo, H.G., dos Santos, L.N., Barros, F., Petruzzella, A., Figueiredo, B.R.S., Pereira, A.D., Latini, A.O., Lopes, A.V., Rosa, C., Vieira Filho, E.A., Evangelista, E.F., Dias, G.M., Ortega, J.C.G., Capel, K.C.C., Abreu, R.C.R. (2024) Capítulo 3: Vetores de mudança diretos e indiretos que afetam a introdução, o estabelecimento e a disseminação de espécies exóticas invasoras. In: Dechoum, M.S., Junqueira, A.O.R., Orsi, M.L. (Org.). *Relatório Temático sobre Espécies Exóticas Invasoras, Biodiversidade e Serviços Ecossistêmicos.* 1a Ed. São Carlos: Editora Cubo, P. 92–132.

Conference proceedings

National Conference Presentations

Weaver, K., Coetzee, J., English, K., Egli, D. and Ngxande-Koza, S. 2024. The Centre for Biological Control's contributions to clean water for all. *Community Engagement Conference.* 14–16 May 2024. Rhodes University, Makhanda, South Africa

Ivey, P. Weaver, K. and Hill, M. 2024. Engaging communities to tackle thorny problem. *Community Engagement Conference.* 14–16 May 2024. Rhodes

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Githae, M., Coombes, C., Mutamiswa, R., Moore, S., and Hill, M. (2024). Susceptibility to parasitism of false codling moth eggs from different sterile to fertile release ratios. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Mushore, T., Coombes, C., Hill, M., and Moore. M. (2024). Biology and management of the fruit-piercing moth, *Serrodes partita*, in citrus orchards. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

de Beer, E., Hill, M., Marsberg, T., Peyper, M., Moore, S., Maree, H., and Bester, R. (2024). Augmentation of *Aphytis melinus* for the control of red scale in citrus. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Cousins, L., Mommsen, W., van Son, E., Simba, V., Saccaggi, D., Mngomezulu, N., Marsberg, T., Peyper, M., Nkomo, S., Mushore, T., Makitla, T., and Moore, S. (2024). Understanding the mealybug parasitoid biocontrol complex: How does it work and when does it fail? *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Moagi, R., Mauda, E., Mukwevho, L., and Hill, M. (2024). An assessment of the status of *psylloid* species as potential pests of commercial citrus in southern Africa: implications for pest management. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

van Steenderen, C., Mauda, E., Kirkman, W., Faulkner, K., and Sutton, G. (2024). The Asian Citrus Psyllid (*Diaphorina citri*) in Africa: using MaxEnt to predict current and future climatic suitability, with a focus on potential invasion routes. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Marsberg, T., Peyper, M., Nkomo, S., Cousins, L., de Klerk, J., Young, A., and Moore, S. (2024). Development of new cold treatments for FCM and their effect on larval survival. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Cardinez, M.C., Moore, S., Hertog, M., and Nicolaï, B. (2024). Volatile profile changes in false codling moth-infested citrus – towards development of a postharvest detection technology. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Mavasa, R.W., Heiduk, A., Johnson, S., Moore, S., and Shuttleworth, A. (2024). Understanding false codling moth oviposition on citrus: analysis of chemical cues used to locate fruit. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Moore, S., Oosthuyse, S., Otto, H., van der Grijp, A., and Beetge, L. (2024). Earlier initiation of FCM mating disruption in the warm northern citrus production areas. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Swanepoel, L., Foord, S., Toussaint, D.C., Thivheleli, K., and Moore, S. (2024). The role of bats as natural pest control agents of moth pests (false codling moth and carob moth) in citrus orchards. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Heiduk, A., Johnson, S., Moore, S., Peyper, M., Cousins, L., and Shuttleworth, A. (2024). Applying chemical ecology methods to improve FCM management strategies. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Oosthuizen, R., and Moore, S. (2024). Post-harvest detection of false codling moth infested fruit using detection canines: building towards commercial application. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Daneel, J., and Moore, S. (2024). Improving packhouse delivery inspections. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Oral Presentation

Adams, L., Martin, G., Steenhuisen, S., & Downs, C. (2024). *The use of ground level imagery to determine fleshy-fruited invasive alien shrubs population change over time along roadsides of South African grasslands. National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Oral Presentation

Baso, N., and Coetzee, J.A. (2024). Fostering trophic resistance to climate change and biological invasions in African freshwater ecosystems. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Oral Presentation.

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Martin, G., Mashamba, T., Steenhuisen, S. and Payne, S. (2024). Beauty and the Beast: A story of *Salix* species in South Africa's Grassland Biome. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Oral Presentation

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Mbele, T. J., Steenhuisen, S. and Canavan, K. (2024). The invasive status of *Cortaderia* species in South Africa. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Oral Presentation

Sexton, W.T., Muskett, P.C., McConnachie, A.J., Portillo, L.M., Viguearas, A.L. and Paterson, I.D. (2024). Prospects for biocontrol of the thistle cholla cactus, *Cylindropuntia pallida* (Cactaceae) in South Africa. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Oral Presentation.

Wilson, J., Faulkner, K., Fernández Winzer, L., McCulloch-Jones, E., van Wilgen, B., Blanchard, R., Carbutt, C., Dechoum, M., Foxcroft, L., Greve, M., Hui, C., Ivey, P., Kgope, B., Kumschick, S., le Roux, P., Masehela, T., Measey, G. J., Miza, S., Mogapi, T., Mpikanisi, F., Mulaudzi, L., Nelukalo, K., Nnzeru, L., Nsikani, M., Pattison, Z., Rahlao, S., Richardson, D., Robinson, T., Schackleton, R., Tererai, F., Tshidada, N., Tshikhudo, P., Tshivhandekano, I., Wanjau, K., Ziller, S., and Zengeya, T. (2024). *A South African perspective on the 2023 IPBES Thematic Assessment Report on Invasive Alien Species and their Control. National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Oral Presentation.

De La Fontaine, B., Mdiza, W., Sutton, G. and Paterson, I.D. (2024). Field surveys and phylogenetics narrow the search for a suitable biological control agent for Guinea grass (*Megathyrsus maximus*). *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Doherty, J., Coetzee, J. and Underhill, L. (2024). Understanding the impact of water hyacinth invasion on avian diversity. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Ivey, P. and Hill, M. (2024). Raising awareness of invasive species and biological control in the social media era. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Jeme, A., Paterson, I., Kumschick, S. and Wilson, J. (2024). *Should effective management lead to a change in the regulatory status of an invasive species: classical biological control as a case study. National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Maneli, S., Muskett, P. and Paterson, I. (2024). Assessing the potential for biocontrol of the Brazilian cactus (*Brasiliopuntia brasiliensis*) by evaluating the efficacy of cochineal lineages primarily used for controlling other species in South Africa. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Mantshi, H., Motitsoe, S., Hill, M., Coetzee, J.A., Mlambo, M.C. and Petruzzella, A. (2024). Short-term effects of invasive free-floating aquatic plant control on macroinvertebrate communities in South Africa. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Masalesa, T., Wasserman, R. and Coetzee, J.A. (2024). Assessing ecological interactions between invasive aquatic plants and mosquito populations using an outdoor mesocosm approach. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol

Plaatje University, Kimberley. Speed Presentation.

Martin, G. (2024). Update on biological control options for invasive trees in the Grassland Biome. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Martin, G. D., Weyl, P. S. R. and Chikowore, G. (2024). *First record of Robinia hispida L. (Fabaceae) in South Africa. National Symposium on Biological Invasions*. 9-12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Mnciva, S., Coetzee, J.A., and Hill, M. (2024). Integrated management of *Pontederia crassipes* using a combination of sublethal herbicide concentrations and the classical biocontrol agent, *Megamelus scutellaris*. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Mukhawana, J., Paterson, I.D., Sandenbergh, E. and Moran, P. (2024). Population genetics of the stem-mining weevil, *Lixus carinerostris*, a potential biocontrol agent for invasive crystalline ice-plant, *Cryophytum crystallinum*. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Muskett, P., Sutton, G.F. and Paterson, I.D. (2024). A long-term, post-release evaluation showing that *Hypogeococcus* sp. is an effective biocontrol agent for queen of the night cactus. *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Sandenbergh, E., van Steenderen, C., Moran, P., Webb, C. and Paterson, I.D. (2024). Using genetic matching to enhance the prospects for the biological control of *Cryophytum crystallinum* L. (Aizoaceae). *National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Zachariades, C. and Martin, G. (2024). *Invasive alien Rubus species in South Africa: which species to target for biological control, current status and the way forward. National Symposium on Biological Invasions*. 9–12th September 2024. Sol Plaatje University, Kimberley. Speed Presentation.

Kambani, T., Jukes, M., Knox, C., Moore, S. and Hill, M. (2024). Evaluating effects of *Cryptophlebia peltastica* nucleopolyhedrovirus and *Cydia pomonella* granulovirus mixtures against *Thaumatotibia leucotreta*. *6th Annual Postgraduate Conference*. 13–14 September 2024. Rhodes University, Makhanda, Eastern Cap.

Luphondo, K. C., Jukes, M. D., Coombes, C.A., Hill, M. P. and Moore, S. D. (2024). Effect of netting on the FCM granulovirus for the management of false codling moth in citrus orchards. *6th Annual Postgraduate Conference.* 13–14 September 2024. Rhodes University, Makhanda, Eastern Cape.

Chikodza, T., Strange, E.F., Wasserman, R. and Coetzee, J. (2024). Do invasive aquatic plants cause an increase in mosquitoes? Concerns for public health. *6th Annual Postgraduate Conference.* 13–14 September 2024. Rhodes University, Makhanda, Eastern Cape.

Mantshi, H.T., Motitsoe, S.N., Hill, M.P., Coetzee, J.A., Mlambo, M.C. and Petruzzella, A. (2024). Short-term effects of invasive free-floating aquatic plant control on macroinvertebrate communities in South Africa. *6th Annual Postgraduate Conference.* 13–14 September 2024. Rhodes University, Makhanda, Eastern Cape.

Doherty, J., Coetzee, J. and Underhill, L. (2024). Understanding the impact of water hyacinth invasion on avian diversity. *National Wetlands Indaba.* 21–25 October 2024. Cape St Francis resort, Cape St Francis Bay, Eastern Cape.

Bute, T.F., Wasserman, R.J. and Coetzee, A.J. (2024). Does heavy metal pollution from acid mine drainage undermine the biological control of water hyacinth (*Pontederia crassipes*) in invaded East Rand wetland systems? *National Wetlands Indaba*. 21–25 October 2024. Cape St Francis resort, Cape St Francis Bay, Eastern Cape.

National Conference Posters

Coombes, C., Hilliar, S., Moore, S. and Hill, M. (2024). Boosting FCM control: Molasses enhances *Cryptophlebia leucotreta* granulovirus formulatio effectiveness. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentations.

Boon, E., Coombes, C., Hill, M. and Moore, S. (2024). Bioprospecting for entomopathogenic fungi for use against foliar citrus pests. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Heiduk, A., Shuttleworth, A., Johnson, S., Peyper, M., Cousins, L. and Moore, S. (2024). Temperature-dependent release rates of false codling moth (FCM) pheromone dispensers used for mating disruption. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Luphondo, K., Jukes, M., Coombes, C., Hill, M. and Moore, S. (2024). Effect of netting on the FCM granulovirus for the management of false codling moth in citrus orchards. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Peyper, M., Moore, S., Kirkman, W., Marsberg, T., Cousins, L., Nkomo, S., Simba, V., Mushore, T. and van der Merwe, M. (2024). A library of cold-treatment shipping efficacies for the false codling moth systems approach. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

van der Merwe, M., Jukes, M., Mumwell, E., Knox, C., Moore, S. and Hill, M. (2024). Development of an advanced qPCR technique for enhanced and accurate enumeration of the baculovirus biopesticide CrleGV-SA. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Jukes, M., Marseberg, T., Moore, S., Knox, C., Hill, M. and Rabalski, L. (2024). *Cryptophlebia peltastica* nucleopolyhedrovirus: A single approach for multiple pests. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Ngxekisa, S., Hill, M., Moore, S. and Coombes, C. (2024). Evaluation of potential repellents for false codling moth, *Thaumatotibia leucotreta* (Meyrick) (Lepidoptera: Tortricidae). *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Nkomo, S., Marsberg, T. and Moore, S. (2024). Challenges in laboratory rearing of *Agathis bishopi*, a larval endoparasitoid of false codling moth. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Tole, S., Hill, M., Moore, S., Jukes, M. and Knox, C. (2024). Evaluating baculovirus mixtures against false codling moth *Thaumatotibia leucotreta* Meyrick. (Lepidoptera: Tortricidae*). 12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Phoswa, S., Hill, M., Moore, S., Jukes, M. and Knox, C. (2024). Cloning and expression of a truncated protein, gp37, from the litchi moth nucleopolyhedrovirus (CrpeNPV) in a bacterial system for improvement of false codling moth granulovirus (CrleGV) infectivity. *12th Citrus Research Symposium*. 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Bennett, T., Mushore, T., Hill, M., Moore, S., Jukes, M. and Knox, C. (2024). The isolation, identification, and characterisation of a novel Alphabaculovirus isolated from the fruit piercing moth, *Serrodes partita*. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Tanka, V., Coombes, C., Hill, M., Mutamiswa, R. and Moore, S. (2024). Low-temperature limits of the mealybugs, *Planococcus citri* and *Pseudococcus longispinus* (Hemiptera: Pseudococcidae) – towards developing a cold treatment schedule. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation

Simba, V., Moore, S. and Hill, M. (2024). Development of parasitism-related intervention thresholds for the management of red scale on citrus. *12th Citrus Research Symposium.* 18–21 August 2024. Champagne Sports Resort, KwaZulu Natal. Poster Presentation.

International Conference Presentations

Kinsler, D., Diaz, R., Snook, J., and Meng, X. (2024). Development of a real-time monitoring tool for Roseau cane health in the Lower Mississippi River Delta. *6th Annual Roseau Cane Research Summit*. 10 May 2024. LSU Hilltop Arboretum, Louisiana, US.

Minuti, G., Gervazoni, P., Nicoló,R., Delange, O., Cantarelli, M., Boon, E., Franceschini, C., Sosa, A., Stiers, I. and Coetzee, J. (2024). Stick to your grubs: a flea beetle to combat the seedling recruitment of *Iris pseudacorus* (Iridaceae), an invasive wetland plant in the Southern Hemisphere. *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Diaz, R., Kinsler, D., Ayala, V, Shackelford, D., Wahl, C., Woodley, S. and Ortiz, J. (2024). Lessons on recovery: Contrasting the impact of biological control of giant salvinia (*Salvinia molesta*) in tropical and subtropical regions. *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Reid, M., Smith, M., Gettys, L., Coetzee, J and Hill, M. (2024). South Africa vs. south Florida: mass rearing and inundative releases of *Megamelus scutellari* s to manage water hyacinth (*Pontederia crassipes*). *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Ayala, V., Herbet, L., Kinsler, D., Gentimis, T. and Diaz, R. (2024). BioControl meets AI: Implementation of real-time satellite monitoring for detection and management of giant salvinia (*Salvinia molesta*). *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Paterson, I., Muskett, P., Griffith, T. and Sexton, W. (2024). Selecting the most damaging biocontrol agents for invasive alien Cactaceae in sub-Saharan Africa. *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Morrison, C., Plowes, R., Woolley, J., Rhodes, A., Sutton, G., Paterson, I, Martin, D. and Gilbert, L. (2024). Tri-trophic plant-herbivore-parasitoid assemblages and diet breadth across native and introduced grasses. *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Sutton, G. van Steenderen, C., Canavan, K., Yell, L., Day, M., Taylor, T., McConnachie, A., Chari, L., Plowes, R., Rhodes, A., Goolsby, J. and Paterson, I. (2024). Biological control of invasive African grasses: progress and prospects. *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Weaver, K., Martin, G., English, K., Ngxande-Koza, S., Ivey, P., Paterson, I. and Coetzee, J. (2024). Promoting biological control leads to improved implementation and long-term sustainability? *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Martin, G. and Ivey, P. (2024). Resolving conflict situations when using biological control against economically useful invasive tree species. *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Langa, S., Hill, M. and Compton, S. (2024). Agents sans frontiers: cross border aquatic weed biological control. *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Hill, M., Sheppard, A., Hinz, H., Rafter, M. and Raghu, S. (2024). Panel Discussion: Biological control in a national and international policy context. *The Third International Congress of Biological Control (ICBC3).* 24–27 June 2024. San José, Costa Rica.

Moore, S., Jukes, M., Mouton, C., Lombard, T., Goddard, M., Hill, M, Iita, P., Taylor, D., Tole, S., Knox, C. and Stenekamp, D. (2024). Challenges and solutions to viral contamination in mass rearing of codling moth and false codling moth for the sterile insect technique. *International Congress on Invertebrate Pathology and Microbial Control and 56th Annual Meeting of the Society for Invertebrate Pathology.* 28 July–1 August 2024. Technical University of Vienna, Vienna, Austria.

Bennett, T., Mushore, T., Hill, M., Moore, S., Jukes, M. and Knox, C. (2024). The isolation, identification, and characterisation of a novel Alphabaculovirus isolated from *Serrodes partita. International Congress on Invertebrate Pathology and Microbial Control and 56th Annual Meeting of the Society for Invertebrate Pathology*. 28 July–1 August 2024. Technical University of Vienna, Vienna, Austria.

Moore, S., Opoku-Debrah, J., Marsberg, T., Jukes, M., van der Merwe, M., Lombard, T., Goddard, M., Grobler, A., Booyens, W., Knox, C. and Hill, M. (2024). Innovative mass production and novel formulation of baculovirus biopesticides for false codling moth management. *International Congress on Invertebrate Pathology and Microbial Control and 56th Annual Meeting of the Society for Invertebrate Pathology.* 28 July–1 August 2024. Technical University of Vienna, Vienna, Austria.

Muleya, N., Phoswa, S., Knox, C., Moore, S., Hill, M. and Jukes, M. (2024). The expression of CrpeNPV gp37 as a formulation additive for improved infectivity with CrleGV against *Thaumatotibia leucotreta*. *International Congress on Invertebrate Pathology and Microbial Control and 56th Annual Meeting of the Society for Invertebrate Pathology*. 28 July–1 August 2024. Technical University of Vienna, Vienna, Austria.

International Conference Posters

Sekgele, W., Moore, S. and Marsberg, T. (2024). Combining SIT and baculovirus application in an integrated approach to management of the false codling moth. *International Congress on Invertebrate Pathology and Microbial Control and 56th Annual Meeting of the Society for Invertebrate Pathology.* 28 July–1 August 2024. Technical University of Vienna, Vienna, Austria.

CBC Research Day

The CBC hosted their third CBC Research Day where students and staff had the opportunity to share their research. It is a great day when most of the not-in-attendance students come to Rhodes University's campus to meet the rest of the team. We host presentations and then move on to the end-of-year function. Thanks to all of the presenters and to the rest of the team for attending the special day.

Back (left to right): Evans Mauda, Martin Hill, Keith Kambini, Raynold Moagi, Sifundo Ngxekisa, Shaun Manzini, Frank Tafare Bute, Wade Sexton, Julie Coetzee, Hlumelo Mantshi, Iain Paterson, Grant Martin, Lyle Titus, David Kinsler, Marcel van der Merwe, Luke Cousins, Eben Mundell, Michael Jukes, Philip Ivey, Guy Sutton, Lenin Chari, Blair Cowie, Landile Booi, Gugulethu Mkile, Byron Soetland.
Middle (left to right): Tahnee Bennett, Nokuthula Kom, Getrude Tshithukhe, Daniel Scholtz, Kurhula Luphondo, Jacky Mukhawana, Julie Coetzee, Rochelle Bessinger, Kelby English, Garyn Townsend, Siya Mnciva, Vhuawelo Simba, Tressia Chikodza, Emma Stirk, Thoriso Masalesa, Siviwe Tole, Clarke van Steenderen, Kim Canavan, Siyabonga Phoswa, Ntando Mkhwanazi, Karabo Moloi, Carmen Peters, Reyard Mutamiswa, Mukololo Khakhu, Benjamin de le Fonteine, Vuyani Ntyinkala, Sive Kolisi, Deric Vershiyi, Nandipha Ngolothi, Riaan Labuschagne, Alungile Jeme, Siya Mini.
Front (left to right): Nompumelelo Baso, Emma Sandenbergh, Caroline Knox, Soso Maneli, Karla Jaschke, Kim Weaver, Erin Boon, Tamzin Griffith, Jaqui van Dyk, Candice Coombes, Jeanne van der Merwe, Samella Ngxande-Koza, Ticia Swanepoel.

Acronyms

AFLP	Amplified Fragment Length Polymorphism
AgriSA	Agricultural Research Council of South Africa
ARC-PPRI	Agricultural Research Council – Plant Protection Research Institute
ARU	Afromontane Research Unit
BBCA	Biotechnology and Biocontrol Agency
CBA	Cost Benefit Analysis
CBC	Centre for Biological Control
CPUT	Cape Peninsula University of Technology
CRI	Citrus Research International
CrleGV	Cryptophlebia leucotreta granulovirus
CrpeNPV	Cryptophlebia peltastica nucleopolyhedrovirus
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEA	Department of Environmental Affairs
DEFF	Department of Environment, Forestry and Fisheries
DALRRD	Department of Agriculture, Land Reform and Rural Development
DPI	Department of Primary Industries
DST	Department of Science and Technology
EPF	Entomopathogenic fungi
EPN	Entomopathogenic nematodes
FABI	Forestry and Agricultural Biotechnology Institute
FCM	False Codling Moth
FuEDEI	Fundación para el Estudio de Especies Invasivas
FURB	Fundação Universidade Regional de Blumenau
ICWG	International Cactus Working Group
IPM	Integrated Pest Management
NCE	Namibian Chamber for Environment
NEMBA	National Environmental Management: Biodiversity Act
NRF	National Research Foundation
NRM	Natural Resource Management
PSHB	Polyphagous Shot Hole Borer
SAAB	South African Association of Botanists
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SAPIA	Southern African Plant Invaders Atlas
SARChI	South African Research Chairs Initiative
SASRI	South African Sugarcane Research Institute
SIT	Sterile Insect Technique
U3A	University of the Third Age
UCT	University of Cape Town
UFS	University of the Free State
UKZN	University of KwaZulu-Natal
UMP	University of Mpumalanga
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
WfW	Working for Water
Wits	University of Witwatersrand

THE CENTRE FOR BIOLOGICAL CONTROL (CBC)
Department of Zoology and Entomology
Life Science Building
Barratt Complex
Rhodes University
African Street
Makhanda

https://www.ru.ac.za/centreforbiologicalcontrol/

Phone: +27 46 603 8763
Email: cbcinfo@ru.ac.za

Twitter: https://twitter.com/RhodesUniCBC
Facebook: https://www.facebook.com/RhodesUniCBC/

CBC Vision

The CBC seeks to:

(i) Sustainably control environmental and agricultural pests for the protection of ecosystems and the societies that depend on them, and

(ii) Ensure that the maximum benefits of biological control are realised through excellence in research, implementation and community engagement.

CBC Mission

The CBC's Mission is to make the Rhodes University Centre for Biological Control an internationally recognised research institute and a leading research centre.

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